November 1984

DCIEM No. 84-R-51

DYNAMIC TESTING OF THE CH135 HELICOPTER RESTRAINT SYSTEM

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ABSTRACT

A series of tests to determine the overall effectiveness of the CH135 helicopter restraint system was performed on the HyGe crash simulator at the Impact Studies Facility at DCIEM. The thirteen impacts utilized a ruggedized, accurate, mock-up of a CH135 pilot's seat, and were conducted to investigate the dynamic behaviour of a new buckle, manufactured by Irvin Industries, as a possible replacement for the older buckle currently used in the CH135 helicopter. Also, the performance of the currently used MA-6 inertia lock reel retractor in both its "automatic" and "locked" modes of operation was studied in simulated impacts for a wide variety of crash severities. Previous tests with this retractor had revealed a "failure-to-lock-up" under certain crash conditions. The excursions of the "occupant" were measured, using high-speed movie cameras, in order to determine the possibility of either the occupant's chest striking the cyclic stick, or his head striking the cockpit sun-shield or control panel. Contrary to some previous experience, in these tests, the retractor locked-up successfully at all impact levels tested, according to the pertinent military specification. In addition, the excursion data showed that, while extra webbing is pulled out of the retractor during impact in the automatic mode, which does increase occupant excursion slightly, the possibility of this causing contact within the cockpit is not significantly increased. The overall restraint system performed well, limiting occupant excursions of sufficient magnitude that only mild impact of the head on the outermost area of the relatively flexible sun-shield was permitted; and, then, only during the most severe crashes from which occupant survival could be expected. On the other hand, the Irvin Industries' buckle was not structurally capable of transmitting the loads imposed on it by the belts, and failed (by pull-out of the belt tongues) at high impact levels.

1. BACKGROUND AND OBJECTIVES

The CH135 helicopter, like many other CF aircraft, utilizes the MA-6 inertia lock reel retractor, which is manufactured by Pacific Scientific of Anaheim, California. This reel applies tension to the shoulder-belt webbing of the typical four- or five-point restraint harness worn by aircrew, and can operate in either of two modes chosen by the seat occupant. In the "automatic" mode, the retractor simultaneously locks the reel and prevents further belt removal from the reel only when a predetermined belt acceleration is exceeded (1.5 - 3.0 G (1,2)); i.e., only when a sudden movement of the occupant in the restraint system occurs. In the "locked" mode, the reel is locked, and the belt cannot be significantly unwound from the reel at any time.

Previous dynamic tests, both at DCIEM and in the U.S.A., have identified a possible catastrophic retractor failure; specifically, failure-to-lock in the automatic mode. This failure had not been thoroughly investigated, and its occurrence appeared to have been random and unpredictable. The retractor manufacturer and other laboratories suspect that this phenomenon may be caused by too high an onset[1] rate of acceleration of the webbing out of the retractor. In addition, the crash severity[2] of the impacts which caused failures had not been thoroughly determined; and the effectiveness of the entire restraint system in preventing impact of the occupant with the interior of the cockpit was not known as a function of crash severity, and initial retractor mode.

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[1] Defined as the rate of change of acceleration, in G/sec.

[2] In order to quantify the severity of a crash, either the Aircraft Crash Survival Design Guide (3) or its predecessor, the Crash Survival Design Guide (4) is normally consulted in order to ascertain the appropriate impact velocity and peak deceleration occurring during an impact. These two extensive reports give a statistical analysis of the impact conditions for various types of U.S. Army rotary and light fixed-wing aircraft which crashed between 1960-65 and 1971-76. A total of 650 accidents were investigated and extensive data are presented concerning longitudinal, vertical, and lateral decelerations and their corresponding changes in velocity. These were plotted in order to show their various interrelationships and, of more importance, to show the "percent cumulative frequency of occurrence" (CFO) of all potentially survivable accidents, as a function of deceleration and impact velocity. The references define the CFO as the fraction, expressed as a percentage, obtained by dividing the cumulative total number of crashes which were judged to be potentially survivable, by the cumulative total number of crashes during the period studied, for a specified impact deceleration level and change in velocity. For example, for an impact of 15 G and 24 miles per hour (mph), these references give a CFO of 80%, indicating that 80% of all potentially survivable crashes occur at decelerations and velocity levels below 15 G and 24 mph.

In addition to concerns about the lock-up feature of the retractor and the possibility of large occupant excursions and impacts within the cockpit, the Canadian Department of National Defence (DND) expressed an interest in an evaluation of a new buckle proposed for the CH135 helicopter 5-point restraint harness system. This is in conjunction with ongoing programs within the Canadian Forces to standardize the restraint systems in many of their aircraft. Two new buckles were identified as possible candidates for the CH135 helicopter, and other DND aircraft:

a. the Pacific Scientific Rotary Buckle System, which is already qualified for use within DND according to Military Specification MIL-S-58095 (AV) (5); and

b. the Irvin Industries Rotary Buckle System, which is not presently qualified.

In summarizing the problems identified above, the broad objective of this test program was to determine the overall effectiveness of the CH135 pilot seat restraint system; and, more specifically, to examine the performance of the MA-6 inertia lock reel retractor in both the automatic and locked modes, and to determine the structural integrity of Irvin Industries' rotary buckle. This can best be accomplished by conducting a series of impacts with increasing peak accelerations and velocities, during which high-speed movie films are used to observe the lock-up performance of the retractor and to measure the excursion of the pilot's head. The integrity of the buckles would also be revealed by such a series of tests.

In order to achieve these objectives, minimize the number of impacts, and to make maximum use of the limited number of rotary buckles and retractors which were available, a program of six test phases was developed, utilizing new and used hardware items in a specified fashion, as shown in Table 1. Each phase had distinct objectives, and utilized hardware efficiently with impacts of varying severity. As shown by the two columns in Table 1 entitled, "SHOULDER WEBBING ACCELERATION" and "SEAT DECELERATION", the acceleration of the shoulder-belt webbing was the determining factor in finding the appropriate crash pulse for some phases of the work; while in others, the seat deceleration was selected, in order to observe other phenomena of interest. For Phases II and IV, several test impacts were carried out in a search for conditions satisfying the objectives shown. The following comments have been supplied in order to clarify, where applicable, OBJECTIVES (a) to (j) in Table 1.

Phase I

Objective (a): Below a certain threshold impact deceleration level, the shoulder webbing is not pulled out by the seat occupant fast enough to lock-up the retractor; i.e., to cause a shoulder webbing acceleration as high as the 1.5 to 3 G which are necessary to cause lock-up. Phase I is required to find the seat deceleration at the first lock-up point, and to

establish the crash severity through use of the CFO value. The results indicate whether or not lock-up of the retractor occurs soon enough (i.e., at a low enough webbing acceleration) to prevent a significant proportion of injuries.

Phase II

Objective (b): This phase was used to demonstrate whether or not the retractor is performing according to those portions of the required specifications (1,2) concerning first lock-up; i.e., that lock-up begins to occur at a webbing acceleration between 1.5 and 3.0 G.

Objective (c): This comment is self-explanatory.

Objective (d): In the forward direction, the inadequately-restrained occupant may strike either the control panel, or the sun-shield attached to the top of the control panel. The objective in this test was to determine the possibilty of such contact for those impacts which produce webbing accelerations slightly above and below those causing first lock-up. As in Objective (a), this helps to determine whether or not lock-up occurs early enough to prevent serious head injury.

Phase III

Objective (e): On impact, in the automatic mode, a certain amount of webbing unwinds from the reel before the webbing achieves the required acceleration to initiate lock-up, and before the latching mechanism can activate and lock the reel. The results from this phase, which is carried out with the retractor in the locked mode, can be compared with the results from Phase II (see Objective (d)), in which the retractor was in the automatic mode. This will determine whether or not there is any significant unwinding of webbing before the retractor locks-up, at the first lock-up point, in terms of preventing excessive head excursions which might result in head impact.

Phase IV

Objective (f): As explained earlier, the MA-6 retractor may fail to lock-up from the automatic mode at some high impact levels. Since the Aircraft Crash Survival Design Guides (3,4) recommend that restraint systems be designed to provide protection for impacts with a 95% CFO value, Phase IV (see Objective (f)) was begun at an intermediate impact severity, which was increased or decreased, as required, to locate the first fail-to-lock point, without exceeding a maximum crash severity yielding a 95% CFO value. The CFO value for the first fail-to-lock point could then be established from the Aircraft Crash Survival Design Guide, and the relative significance of the lock-up failure determined. For example, such a failure is likely unimportant if it ocurs only at extremely high CFO and deceleration levels (i.e., levels above which most aircrew could not be expected to survive in any event). However, if the failure were to

occur at relatively low deceleration and CFO levels (ones which aircrew could be expected to survive), it would be of considerable importance, since such a failure could lead to unnecessary injury or death.

Objective (g): The objectives here were similar to those outlined in Phase II, Objective (d), but with the retractor in the automatic mode, and for the first fail-to-lock point at the high impact level found in Objective (f).

Phase V

Objective (h): The objectives here were similar to those outlined as Objective (e), but for the first fail-to-lock point at the high impact level found in Objective (f).

Objective (i): This comment is self-explanatory.

Phase VI

Objective (j): This comment is self-explanatory.

2. TEST METHODOLOGY

2.1 Test Equipment and Instrumentation

The tests were executed on the DCIEM 12-inch HyGe (Bendix Corp) impact accelerator, which simulates impact by rapid acceleration, or, as it is commonly called, a "reverse mode" impact. The crash acceleration pulse delivered to the test package was determined by the adjustment of various gas pressures and volumes within the HyGe accelerator, and by the selection of an appropriate profile for an internal metering pin, which determines the precise shape of the acceleration pulse. The test sled, with its payload, was accelerated in a backwards direction to a pre-determined velocity. During this short period of rapid acceleration, the sled and on-board payload experienced the same dynamic loads that would occur during a sudden deceleration impact. After the initial acceleration, the sled was slowly decelerated to a stop.

As shown in Table 1, the test program called for the use of a number of different peak pulse seat accelerations. However, as noted earlier, the Crash Survival Design Guides (3,4), contain a large amount of data collected from many accidents, which permit the determination of both the required peak acceleration and the change in velocity needed for any desired crash severity. Therefore, the Guide was consulted to correlate peak acceleration and velocity for each test in this program for a HyGe actuator metering pin which produces a one-half sinusoid acceleration pulse profile.

For the test payload, a mock-up of a CH135 helicopter pilot/co-pilot's seat was fabricated at DCIEM, using manufacturer's blueprints

and photographs of existing seats. Only the seat-pan and back, and the bracket to which the retractor is bolted, were fabricated at DCIEM. They were made as identical as possible to a production-line seat. The seat assembly is shown in Figure 1(a). The supporting structure for these parts and a fake cyclic stick, were also designed and fabricated at DCIEM, solely to provide a very ruggedized, impact resistant interface for the secure attachment of the seat, rectractor, and fake cyclic stick to the impact sled. The cyclic stick was located as if it were in its extreme rearward position, with the seat full forward and raised one-half way towards the top of its travel. These conditions were intended to simulate the maximum risk to the occupant. The two seat pads, which fit onto the seat pan and back were obtained from the original seat manufacturer, and are shown installed in Figure 1(b). Side and front views of the seat with dummy mounted on the impact sled are shown in Figures 2 and 3.

A number of MA-6 inertia lock reel retractors were purchased, through the DND supply system, for the tests. These retractors had seen previous service, and had then been refurbished by a qualified distributor for re-use by DND. After they were sent to DCIEM, a short, hexagonal, hollow shaft was inserted into one end of each in order to make a connection with the reel within the retractor. A flat, machined disc was attached to this shaft, so that the reel rotation could be recorded by a movie camera. Several retractors were used for more than one impact each, but only when a critical retractor function was not being studied, and/or when a retractor was used in the "locked" mode. These retractors are readily identified in the "retractor number" column in Table 1.

The "occupant" of the ejection seat was a 95th-percentile adult anthropomorphic crash-test dummy (Alderson Research Labs, Stamford, Connecticut, U.S.A.; Model VIP-95, Serial No. 158, conforming to the United States Code of Federal Regulations (6)). It was instrumented in the chest cavity with an Endevco type 7267C-750 triaxial accelerometer in order to monitor chest deceleration and to assist in detecting chest contact during the impact. The accelerometer was oriented within the dummy along three orthogonal axes such that positive X was in the direction from the back to the front of the dummy, positive Y was in the direction from the dummy's right side to its left, and positive Z was in the direction from the feet to the head.

The dummy was clothed only in an over-sized undershirt. A double layer of seat-cushion material was placed below the dummy in order to reduce the unrealistically high friction between the dummy and bottom seat-pad structure. In order to permit meaningful comparisons of the dummy excursions between the different test impacts, it was necessary to ensure that the dummy was seated in the same position for each test, as much as possible. Consequently, seve.al measurements of the distances between certain dummy features and the seat were taken before the first impact, and then carefully duplicated before each subsequent impact. These included the following:

- the distance between the middle of the back at the height of the shoulder blades, and a fixed point on the seat-back;

- the distance between a target placed on the hip of the dummy and the seat in all 3 coordinate directions; and

- the distance between the feet and the seat in all 3 coordinate directions.

In addition, the distance between the retractor and the end of the retractor-webbing was kept constant.

The loads in both sides of the lap-belt webbing, and the anti-G and shoulder-belt webbing, were measured using Lebow model 3419 belt load-cells. In order to allow sufficient shoulder-belt webbing behind the neck of the dummy for locating a load cell, a 3/4 inch thick foam pad was placed behind the middle of the dummy's back, as shown in Figure 2, which caused the dummy to lean slightly forward. This should not have effected any of the results significantly.

The two shoulder-belts are sewn together behind the dummy's neck, and the single, resultant shoulder-belt then passes through a slot in the seat-back, and reaches half-way down the rear side of the seat-back. A metal attachment plate fastens this belt to another one, which continues down the rear side of the seat-back, and into the retractor (which is fastened to the sled structure near the base of the seat-back). Figure 4 is a photograph of the rear of the seat, with the darker shoulder-belt at the top, and the lighter retractor-belt at the bottom. In order to measure the acceleration of the retractor webbing, 2 miniature accelerometers (Endevco Model 2264-200 single-axis type) were used. One was fastened directly to the metal attachment plate; and the other, as a backup and a check for the first, to a small plate which, in turn, was sewn to the webbing a few inches above the metal attachment plate as shown in Figure 4.

The outputs from each of these 2 accelerometers were amplified at two different gains, which usually differed by a factor of 10. This permitted relatively fine resolution of the initial shoulder-belt acceleration, on the order of several G's, while still capturing the peak shoulder-belt acceleration, typically on the order of 40 G.

Basic sled acceleration data were monitored using 2 Sectra Model 141 high-output accelerometers, which were mounted directly on the HyGe sled.

In order to record the maximum force with which the chest would strike the fake cyclic stick during any of the impacts, a single-axis GSE femur load-cell, Model # 2430, was attached to the top of the fake cyclic stick and directed at the chest. This can be seen in Figures 2 and 3, immediately above the dummy's knees.

For high-speed filming, one ruggedized high-speed Locam pin-registered movie camera was mounted on an outrigger, providing a lateral view of the seat. This camera was equipped with a 10-mm wide-angle lens and was operated at a speed of 500 frames per second. In addition, one high-speed Stalex rotating prism movie camera was positioned on the laboratory floor, in order to provide an oblique angle view of the impact. This camera was also equipped with a wide-angle lens (13 mm), but operated at a speed of 1000 frames per second. In order to determine the maximum belt pull-out from the reel, and to observe any irregular motion of the 2 shoulder webbing accelerometers, a third high-speed Stalex movie camera was mounted behind the seat, viewing the area extending from the retractor up to several feet above the retractor. The view from this camera is nearly identical to that shown in Figure 4.

Two Graph-Check sequence cameras were set up so that "quick-look" photographs of events during the impact were available. These cameras take eight separate photographs on a single sheet of Polaroid film, at pre-selected equal intervals, and permit viewing immediately after the impact.

Before and after each run, photographs were taken of the sled and seat configuration. These photographs are identified by the last digit of the test run number, which is photographically reproduced in the corner of each frame.

2.2 Data Recording and Processing

The output from the accelerometers was amplified on board the sled, using a series of specially designed, ruggedized, low-noise preamplifiers. The signals were analog filtered at 5 kHz on board the sled and were then transmitted along a low noise, flying-lead umbilical cable to the recording and data reduction area. Signals were stored in a multi-channel transient recorder (Datalab, Surrey, UK), which digitized the input signal from each channel synchronously with every other channel, at a sampling rate of 10 kHz. The digitizer accuracy was 10 bits (1 part in 1024) and the total recording time of the digitized data was 0.4 seconds, which was sufficient to capture all significant impact and rebound inertial and belt load data. Complete details of the Impact Studies Facility's data acquisition system have been published (7). The digitizer and recorder equipment specifications are more stringent than the requirements established by the Society of Automotive Engineers (SAE), which sets standards for instrumentation for dynamic test purposes (8).

Immediately after firing the sled, the data were transferred to a computer disk for processing. (The raw data for all runs are retained indefinitely on magnetic tape in the DCIEM computer centre.) The computer programs first performed digital filtering on the data according to the SAE specification (8) which details the specific filtering to be carried out on signals emanating from various sources. For these tests, the sled and chest accelerations were recorded, as well as the belt load force.

The inertial data were appropriately filtered, as specified, at 60 Hz and 180 Hz, respectively. The belt load force was filtered at 60 Hz. The data were then scaled and the resultant chest acceleration computed, along with the sled displacement and velocity, by successive integration of the sled acceleration. Appropriate graphs were produced by a plotter under the control of the computer.

3. RESULTS

For all runs, complete data from the accelerometers (sled, dummy chest, and shoulder-belt webbing), and the 4 belt load-cells (east and west lap, shoulder, and anti-G) are given in Appendix A in plotted form. The most important data have been summarized, and are presented in Table 2, along with data from the high-speed movie films. The film data included in the table represents the measurement of the maximum amount of belt which pulled out from the retractor during impact. (This is the main method for determining whether or not the retractor failed to lock-up.) Other pertinent data concerning test set-up conditions, the state of the retractor after the impact, and the onset rate of the retractor webbing, for each run have also been included, along with the identification of the runs in each of the six test phases.

Phase I

Objective (a): Since the impacts for this phase were very mild, and the results would be verified by the results from Phase II, only a single retractor was used for this phase for as many runs as were required to achieve the objective. After 3 runs had been completed, it was shown (by runs #468 and #469) that the retractor began to lock-up at peak sled accelerations between 1.6 and 2.5 G, with corresponding velocities of 7.2 and 9 miles per hour (mph), respectively. This represents a very low CFO value of 5%. The test showed that about 1 inch of webbing was released from the retractor when lock-up occurred, while the full 7.0 inches of webbing available on the reel was unwound when lock-up failed to occur.

Phase II

Objective (b): Using a previously untested, refurbished retractor for each sled firing, it was determined from runs #470 and #471 that the retractor successfully locked up at a peak shoulder-belt webbing acceleration of 3.5 G, but not at 2.1 G. The values suggest that these two particular retractors performed within the required specification range; i.e., lock-up to begin between webbing accelerations of 1.5 G and 3 G (1,2). The maximum onset rate of acceleration for the 3.5 G lock-up condition was 570 G/sec, and the maximum webbing pull-out from the reel for this run was 0.75 inches. Sled performance for the two runs was recorded at 2 G and 1.5 G, and 9.1 mph and 7.3 mph, respectively. These performance values are in close agreement with those found in Phase I, which utilized the same, previously tested, retractor for each sled firing.

Objective (c): Since the CFO value (5%) found in (a) and (b) above was so low, resulting in a peak belt tension of only 490 pounds for the shoulder-belt, the Irvin buckle was not used in this phase. The results of tests with the Irvin buckle at much higher CFO values and more demanding tensions are reported under the results of Phase VI.

Objective (d): In the forward direction, the occupant, if not sufficiently restrained, may strike either the control panel, or the sun shield attached to the top of the control panel. With the seat full forward and raised halfway towards the top of its travel, the tests showed that the occupant's head moved in front of, and well above, the control panel and sun shield for both conditions bracketing the lock-up point found in Phase I. Specifically, the trajectory of the leading edge of the head passed, at a minimum, 16.4 inches and 11.4 inches from the front edge of the sun shield, for the "locked" and "fail-to-lock" runs respectively. The locations of these two extremes for runs #470 and #471 are shown in Figure 5, relative to the seat-pan and back, the cockpit floor, the control panel and attached sun shield, and the top of the cyclic stick in its most rearward position.

Phase III

Objective (e): With the retractor in the locked mode, as shown in Figure 5 for run #472, the leading edge of the occupant's head passed at a distance of 15.2 inches from the edge of the sun shield. This agrees reasonably well with the minimum distance of 16.4 inches found in Phase II (run #470), in which the impact parameters were identical, and the retractor was required to lock-up from the automatic mode. Film analysis showed that locking the retractor prior to impact reduced the amount of webbing that was released from the retractor during the impact from 0.75 inches to 0.25 inches.

Phase IV

Objective (f): Five sled firings were conducted, using a new retractor for each firing, with each retractor initially in the automatic mode. Peak sled accelerations and velocities ranged from a low of 15.1 G and 24 mph to 25.3 G and 34 mph, which represent CFO values of 80% and 95%, respectively. All of the retractors locked up successfully, with webbing pull-outs varying from a minimum of 0.875 inches to a maximum of 1.125 inches. Film analysis showed that, in most cases, about 50-75% of the pull-out was a result of spool packing, while the remaining 25-50% was due to reel slippage at the onset of belt movement, presumably before the tooth within the retractor had had time to engage the locking ratchet gear. Webbing onset rates of accleration for these tests varied from a low of 910 G/s to a high of 2640 G/s.

Objective (g): Since the retractor successfully locked-up during all of the runs in this phase, the excursions of the occupant were determined only for the two most severe crashes; i.e., at the 95% and 92% CFO levels,

demonstrated by runs #480 and #477, respectively. The results of the film analysis are shown in Figure 5. At the 95% CFO level, the occupant's head would strike the outermost 2 inches of the sun shield, but would not strike the control panel below the sun shield. In the next most severe crash (CFO level 92%), the occupant's head would narrowly clear the edge of the sun shield.

Phase V

Objective (h): Since the retractor successfully locked-up during the tests in Phase IV, the excursions of the occupant with the retractor in the locked mode were determined only for the most severe crash condition; i.e., at a CFO value of 95%. Film analysis of run #478 for this condition showed that the occupant's head would travel to within 0.5 inches of the top surface of the sun shield, but would not strike the shield. A comparison of these results with the results in (g) for run #480, which was performed with an identical acceleration pulse, but with the retractor set in the automatic mode, shows that the extra webbing which plays out of the retractor before the shoulder-belt is arrested allows the head to move further downward by about 1.5 inches, and to strike the sun shield.

Objective (i): See Phase VI for the results of all tests with the Irvin buckle.

Phase VI

Objective (j): Two impacts were performed (runs #478 and #479) using the two Irvin buckles, with the retractors in the locked position. In the most severe impact (run #478, CFO level of 95%), the anti-G belt tongue, and both shoulder-belt tongues, pulled completely out of the buckle. The peak shoulder-belt load, measured behind the dummy's neck on the single belt, was 1970 pounds. This value is about 100 pounds lower than that found in a subsequent, identical pulse impact (run #480), which utilized a Pacific Scientific buckle that had already been used several times and had not failed. During the second sled firing, at a reduced CFO (82%), none of the tongues pulled out of the Irvin buckle.

4. CONCLUSIONS

At the minimum sled acceleration required to induce lock-up of the retractor from the automatic mode, the observed acceleration of the webbing as it left the retractor was very close to the required specification of 1.5 - 3.0 G. This occurred at a very low CFO value of 5%, and resulted in very little occupant movement whether the retractor was in the locked or automatic mode, indicating that first lock-up of the retractor occurs during exceedingly mild impacts. Any occupant excursions that would occur with less severe impacts, during which lock-up would not take place, are insignificant in terms of occupant excursion and impact.

In the automatic mode, the retractor continued to lock-up successfully up to, and including, a CFO value of 95%, which represented the most severe crash simulated throughout the test program. Any lock-up failures that might occur would have to do so at impacts with higher CFO values, and/or at onset rates greater than 2560 G/s. At the 95% CFO level, film analyses showed that the occupant would strike the outermost 2 inches of the sun shield if the retractor was in the automatic mode. It should be noted, however, that the sun shield is not very rigid, and that striking it 2 inches from its edge while wearing a helmet would cause little or no injury to the subject. In the locked mode, the occupant would not make contact with the shield. Since there was never any contact with the control panel below the shield or the simulated cyclic stick, during any of the tests, the restraint system in its entirety appears to be providing adequate restraint for the occupant. In addition, since reel slippage accounts for only about 25-50% of webbing pull-out in automatic mode operation, and the maximum pull-out recorded was less than 1 inch, the use of the automatic retractor mode, during severe impacts up to the 95% CFO level, does not appear to be significantly more dangerous than the use of the locked mode.

The Irvin buckle performed poorly at the 95% CFO level, since both shoulder-belt tongues and the anti-G belt tongue pulled out of the buckle. While it passed at the 82% CFO level, this is considerably below the 95% CFO level which is recommended by the Aircraft Crash Survival Design Guide (3,4) for design purposes. Consequently, this buckle, in its present form, is not recommended for use by the Canadian forces.

ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance of Captain D. Geddes of NDHQ, Ottawa, for his advice and for supplying hardware for the tests, and of the following DCIEM staff: Mr. D. Dennison and Mr. G. Thagard, who performed all the technical operations required for the set-up of the chairs, and the sled firings; Mr. R. Cardin, who provided editorial assistance; and Dawn Gardham, who typed the report.

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(a) Without seat pads

(b) With seat pads

Figure 1. Mock-up of CH135 Pilot/Co-pilot Seat

Figure 2. Side View of Seat and Dummy Mounted on Sled

Figure 3. Front View of Seat and Dummy Mounted on Sled

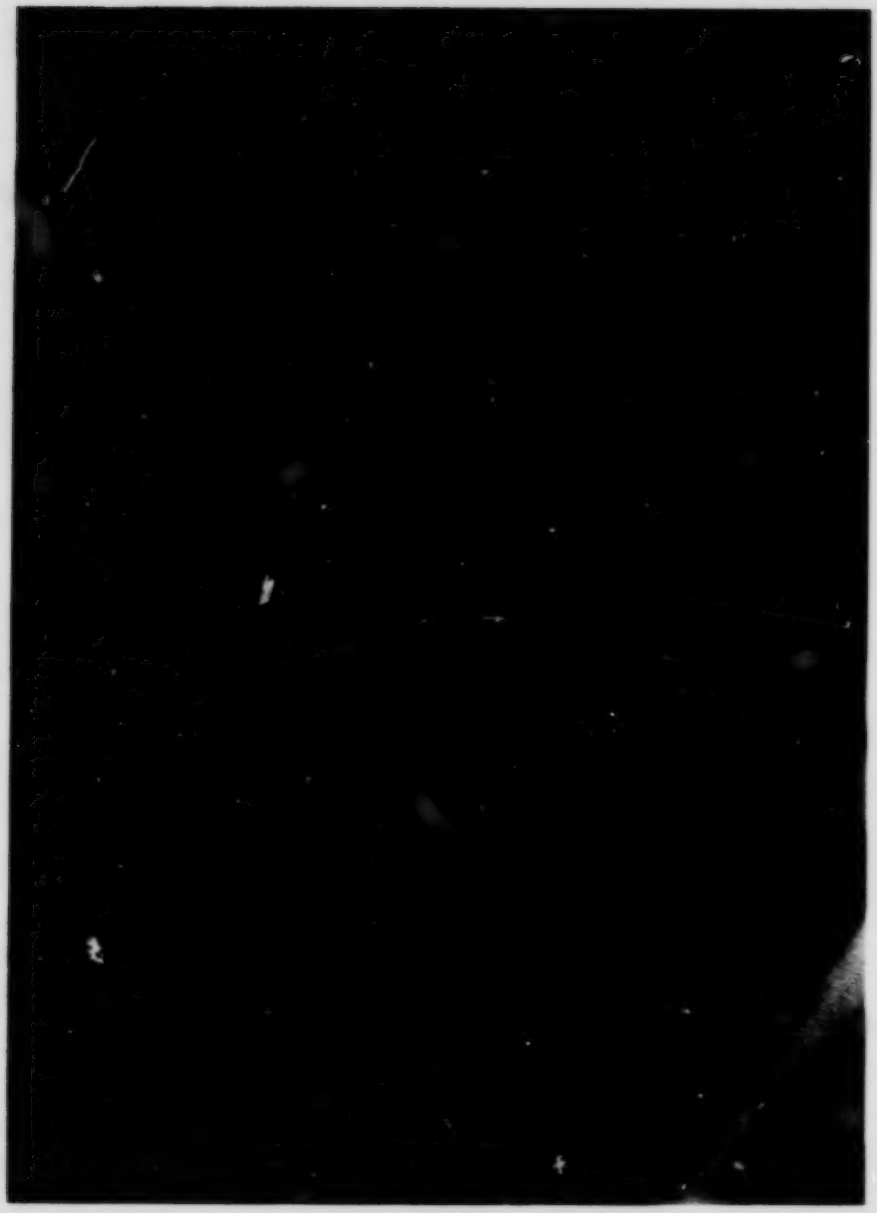


Figure 4. Rear View of Seat Mounted on Sled

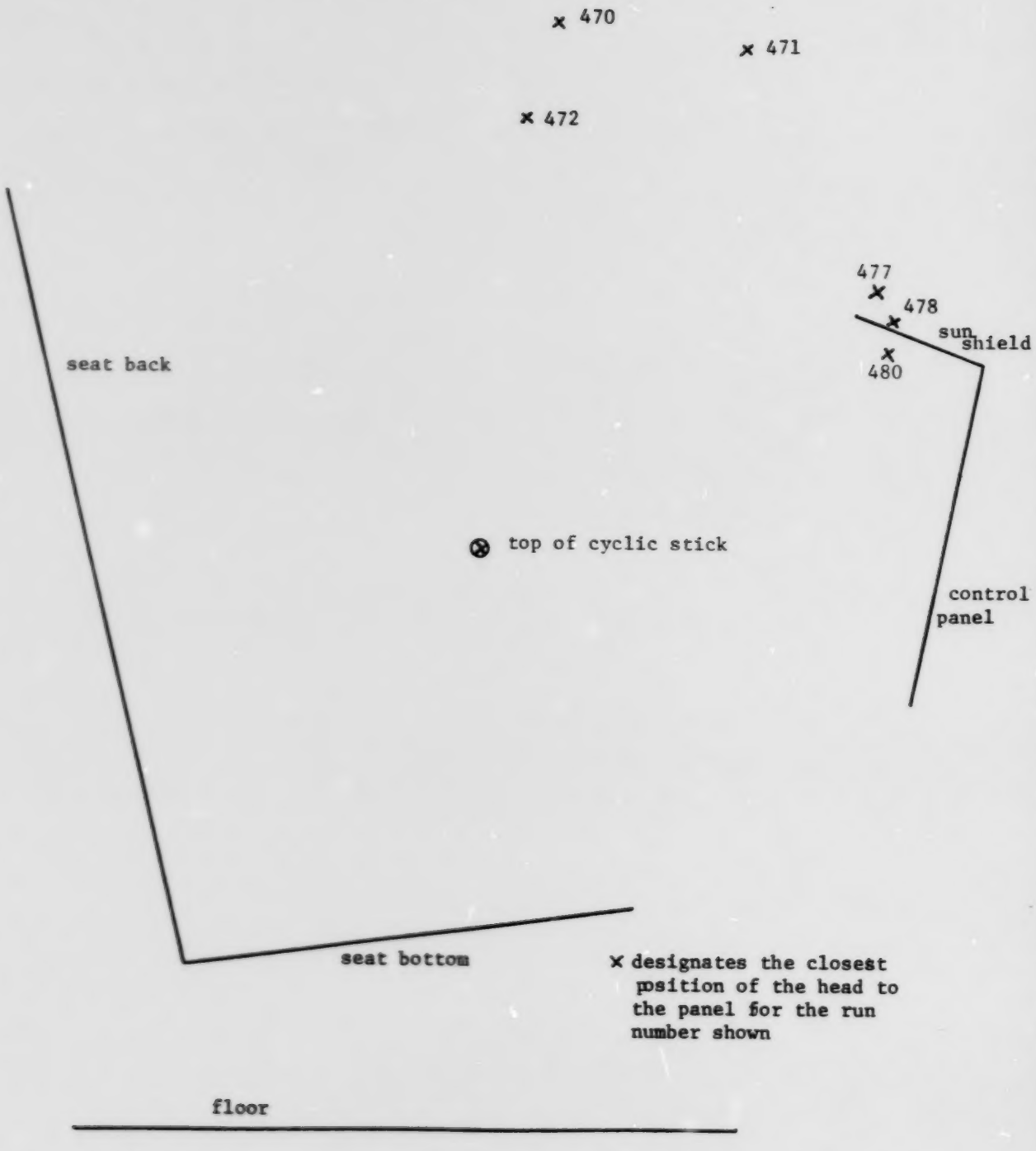
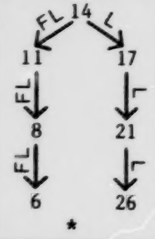


Figure 5. Location of Head Extremity Closest to the Control Panel During Impacts

Table 1: Description of Test Phases

TEST PHASE	EXPECTED NUMBER OF IMPACTS	RETRACTOR NUMBER: MODE AUTO	RETRACTOR NUMBER: MODE LOCKED	BUCKLE TYPE IRVIN	BUCKLE TYPE PACIFIC SCIENTIFIC	SHOULDER WEBBING ACCELERATION (G's)	SEAT DECELERATION (G's)	OBJECTIVES
I	3	1 1 1			X X X	Approaching 3 G by trial and error		(a) To determine the approximate minimum seat deceleration necessary to initiate retractor lock-up (i.e., 1.5 to 3 G's on the belt), and to relate this to crash severity.
II	3	2 3 4		X X X				(b) To determine the shoulder webbing acceleration level at which lock-up first occurs. (c) To verify the integrity of the IRVIN buckle near 3 G's of shoulder webbing acceleration. (d) To determine and compare the occupants maximum forward excursion for the 2 conditions "bracketing" the lock-up point.
III	1		5		X	At lock-up point found in Phase II		(e) To determine the occupant's maximum forward excursion at the lock-up point found in Phase II, with the retractor initially in the "locked" mode (for comparison with the results from (d).
IV	4	6 7 8 9			X X X X			(f) To determine if the retractor fails to lock up, in the auto mode below the 95% CFO value, and the crash severity at which this occurs. (g) To determine the occupant's maximum forward excursion in the 6-26 G region, for the 2 conditions "bracketing" the failure-to-lock point, if found in (f) above.
V	1		9	X			At fail-to lock point found in Phase IV	(h) To determine the occupant's maximum forward excursion at the fail-to-lock poiint found in Phase IV, with the retractor initially in the "locked" mode (for comparison with the results from (g)). (i) To verify the integrity of the IRVIN buckle at moderate-to-high seat deceleration levels
VI	2		9 9	X X			25 or less	(j) To verify the integrity of the IRVIN buckle at relatively high seat deceleration levels.

*Pathway is chosen according to retractor operation in previous run: FL - retractor fails to lock; L - retractor locks.

Table 2: Summary of Test Data

	Phase			I			II		III	IV					V VI	VI
	Run Number			467	468	469	470	471	472	475	476	477	480	481	478	479
SET UP DETAILS	Retractor	Serial Number		spare unit used			236 90	933 46	933 46	236 72	123 30	250 76	243 29	679 41	spare unit used	
		Mode	Automatic	X	X	X	X	X		X	X	X	X	X		
			Locked						X						X	X
	Buckle Type		Irvin												X	X
			Pacific Scientific	X	X	X	X	X	X	X	X	X	X	X		
	Movie Camera Coverage		Offboard	X			X	X	X	X	X	X	X		X	X
			Lateral	X	X		X	X	X	X	X	X	X	X	X	X
			Rear of Seat	X	X	X	X	X	X	X	X	X	X	X	X	
TEST RESULTS	Peak Seat Acceleration (G's)			3.6	2.5	1.6	2.0	1.5	2.0	15.1	17.9	21.3	25.3	17.0	25.5	14.4
	Maximum Seat Velocity (MPH)			11.5	9.0	7.2	9.1	7.3	9.1	24.0	26.2	31.4	34.0	27.9	34.2	25.6
	Retractor Condition After Impact		Locked	X	X		X		X	X	X	X	X	X	X	X
			Unlocked			X		X								
	Webbing Pullot from Retractor (inches)			1.0	1.0	7.0	0.75	7.0	0.25	0.87	1.0	1.0	1.12	0.87	0.75	0.75
	Peak Retractor-Webbing Onset Rate (G's/sec)			---	---	---	570	410	---	910	1200	1970	2640	1050	---	---

APPENDIX A:

Belt Load and Inertial Data

The data are grouped in chronological order by run number: on the plot pages the run number is given by the 3 digits on the second line of the heading on each "page 1". The same number can also be found at the top left corner of all subsequent pages of the same run: e.g., the "page 1" whose second line reads DK:DFS471.DAT is the first page of the data for run #471. For each run, the plots are presented in the following order:

Page 1, sled displacement, velocity, and acceleration

Page 2, west lap-belt load (pounds),
east lap-belt load (pounds),
shoulder-belt load (pounds),
anti-G belt load (pounds);

Page 3, low-range, shoulder-belt acceleration, measured on the webbing,
high-range, shoulder-belt acceleration, measured on the webbing,
low-range, shoulder-belt acceleration, measured on the attachment plate,
high-range, shoulder-belt acceleration, measured on the attachment plate; and

Page 4, chest acceleration in the X-direction
chest acceleration in the Y-direction
chest acceleration in the Z-direction
resultant chest acceleration

The maximum value of each plot is printed above, and at the right side of each plot.

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DK:DFS467.DAT

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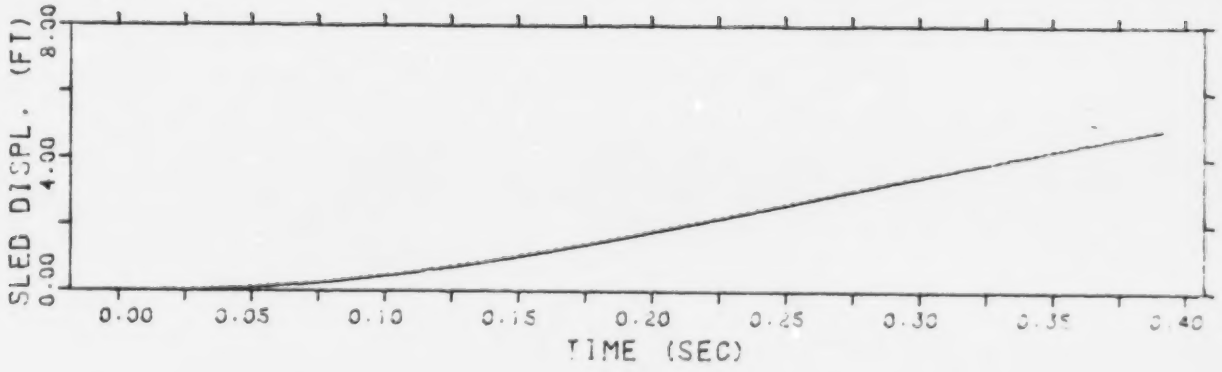
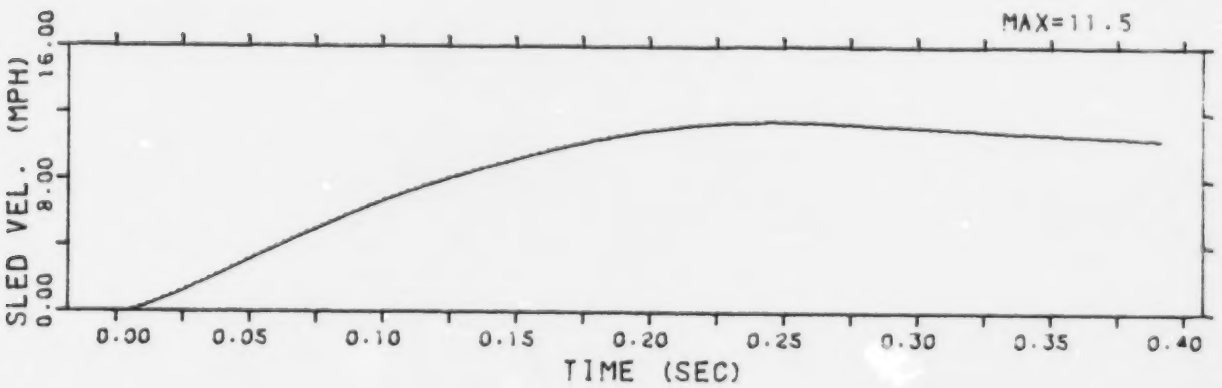
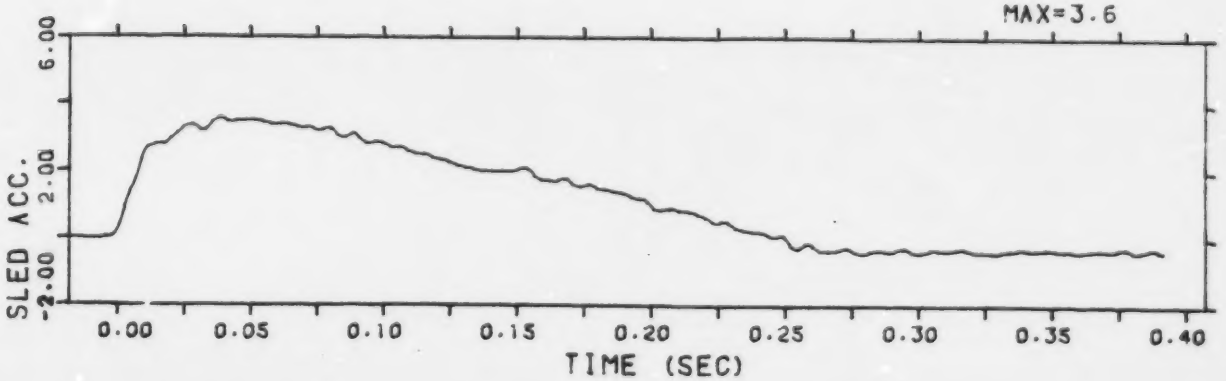
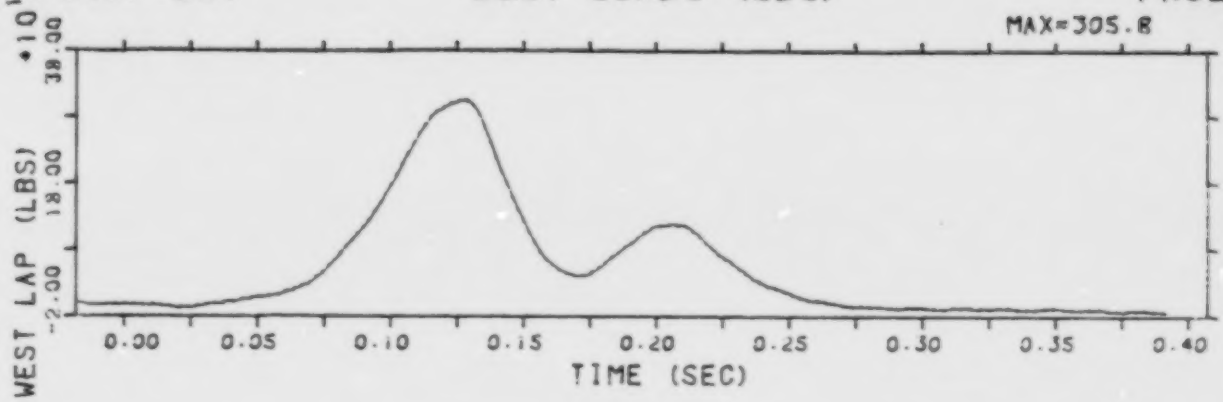
09:06:34





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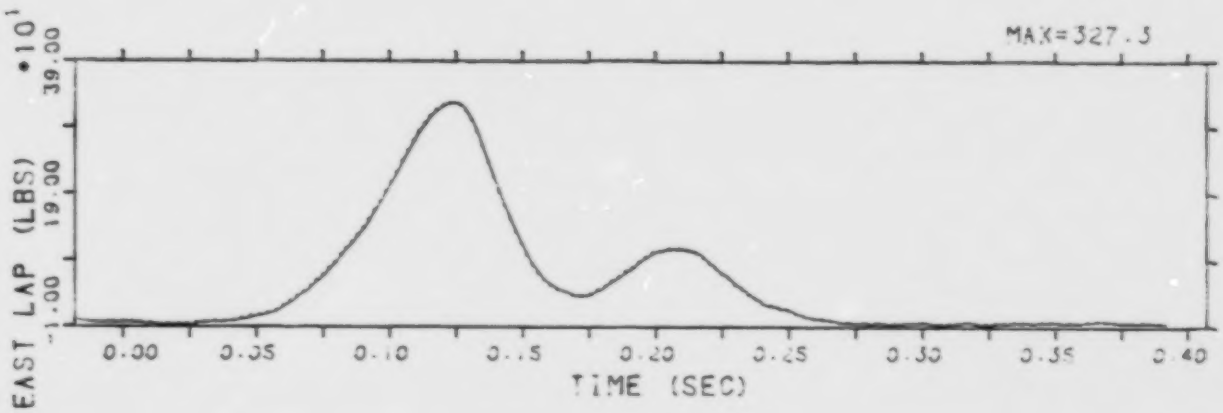
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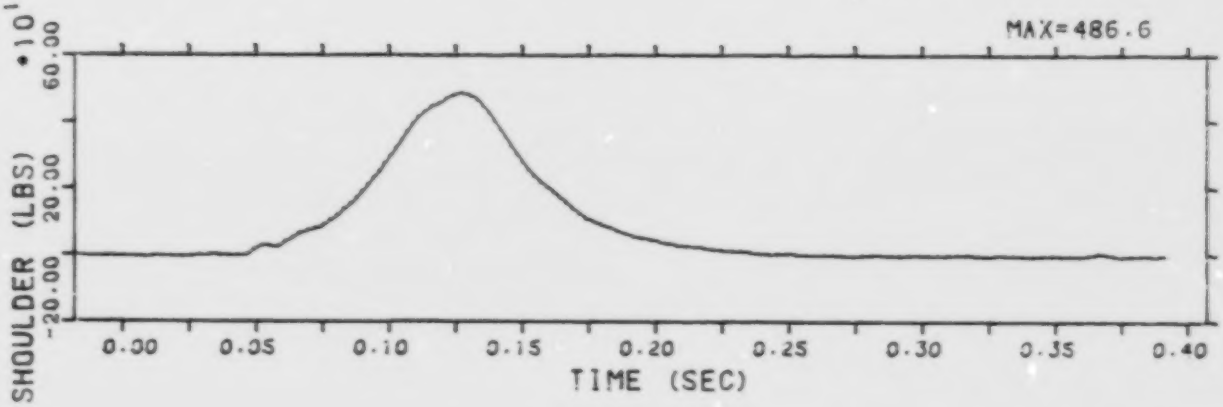
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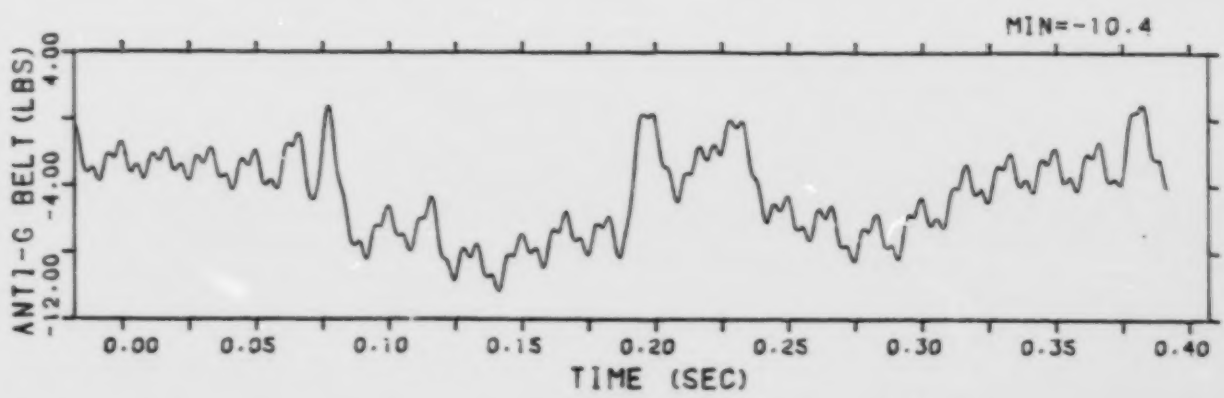
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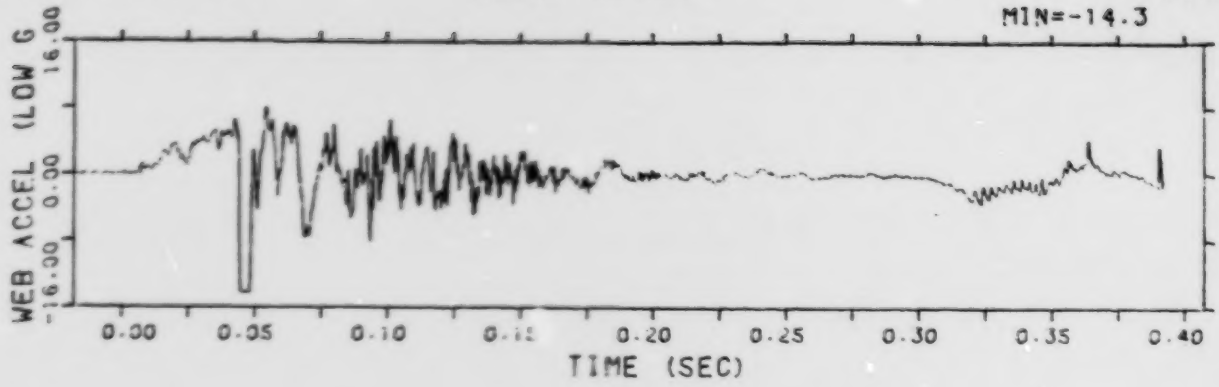
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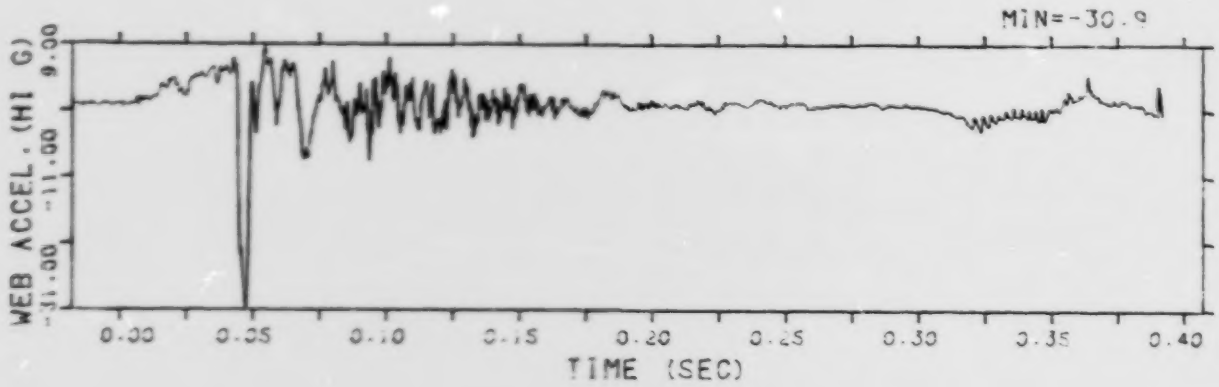
0.20
0.25
0.30
0.35
0.40
TIME (SEC)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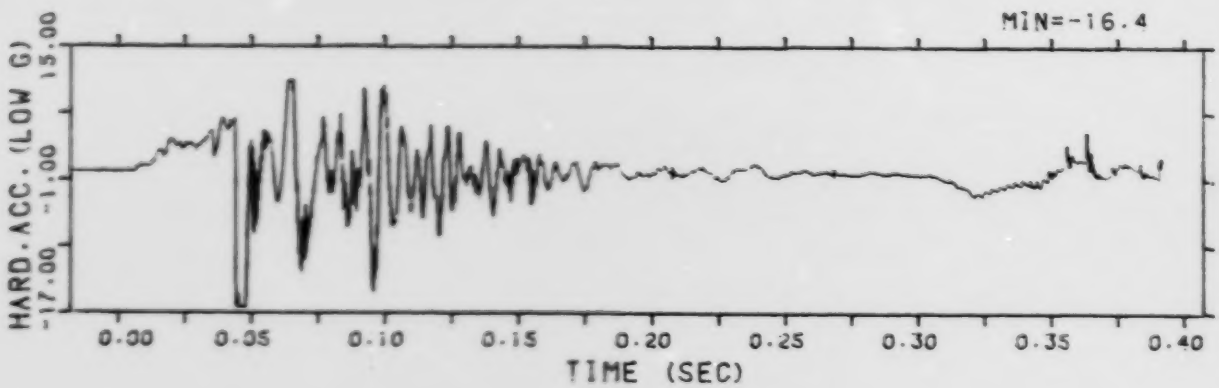
0.25
0.30
0.40
TIME (SEC)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0.20
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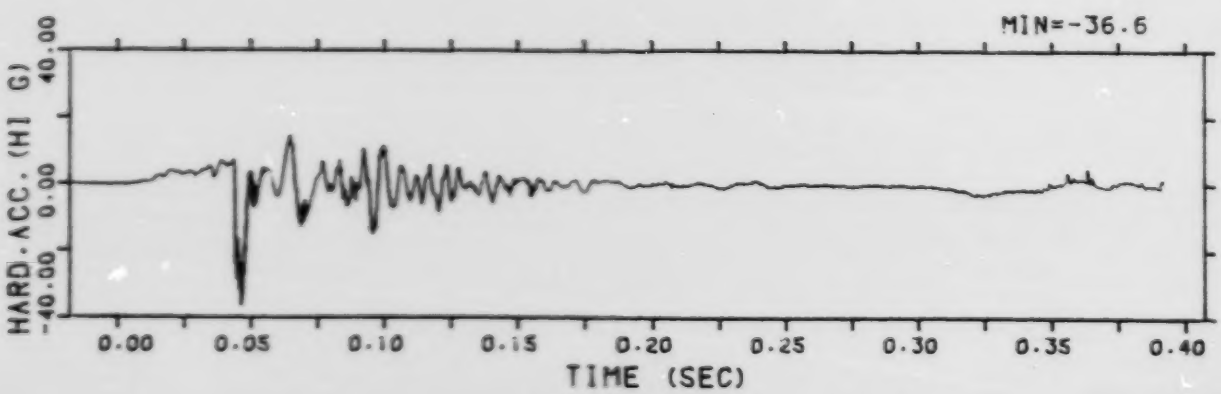
0.35
0.40
TIME (SEC)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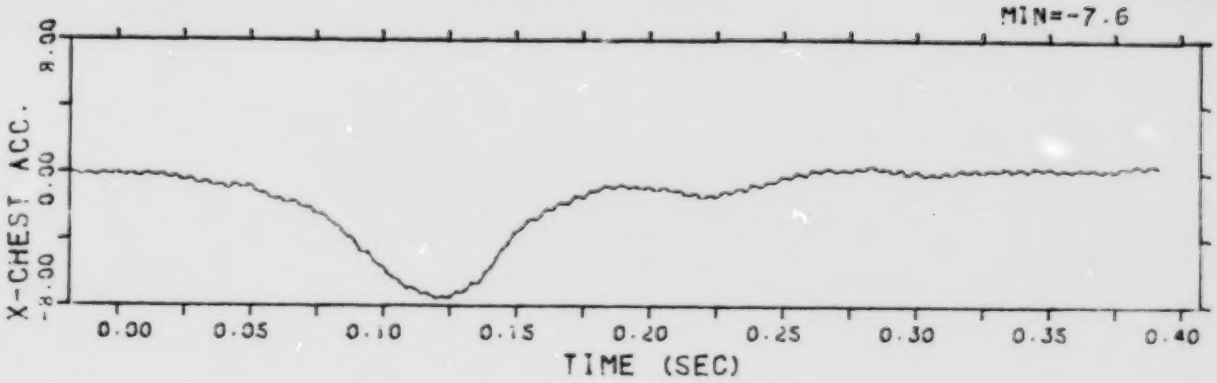
TIME (SEC)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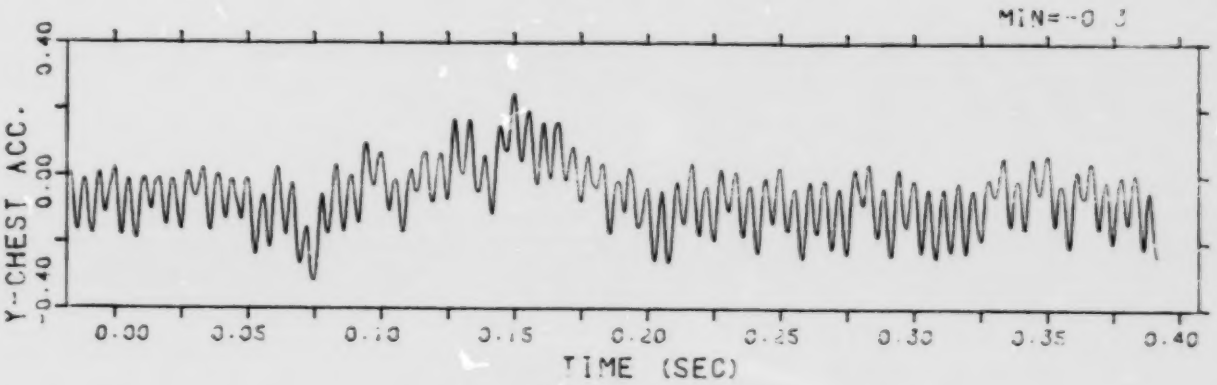
TIME (SEC)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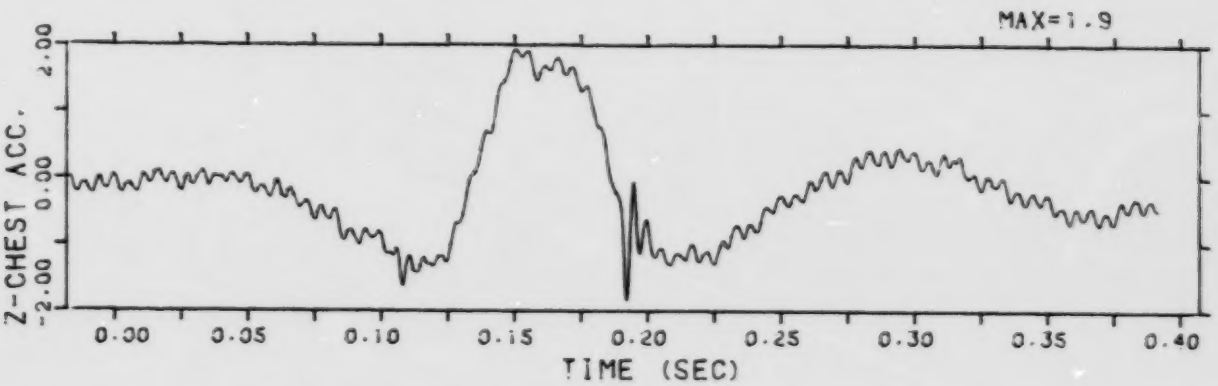
TIME (SEC)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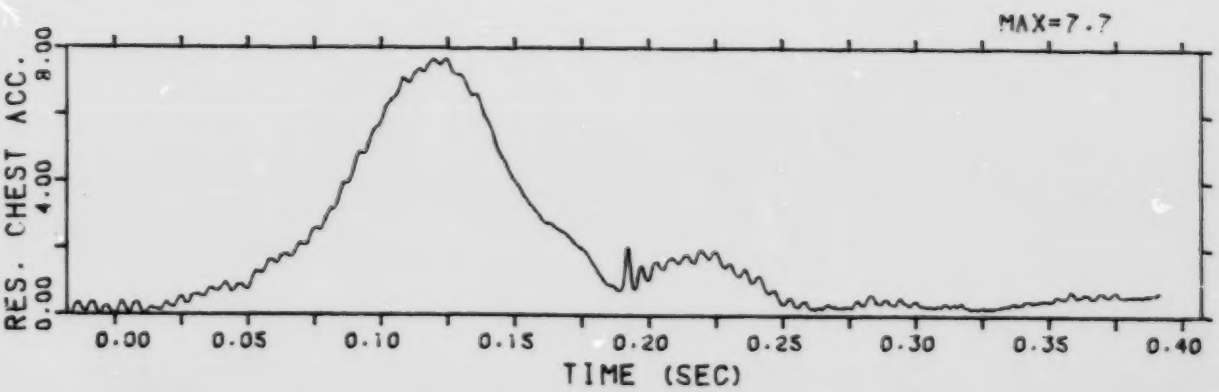
0.40
TIME (SEC)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0.20
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0.30
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0.40
TIME (SEC)

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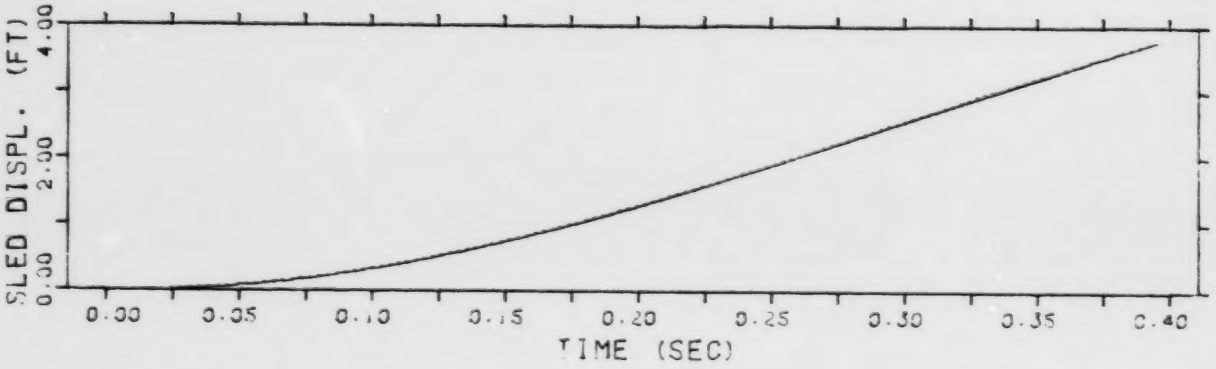
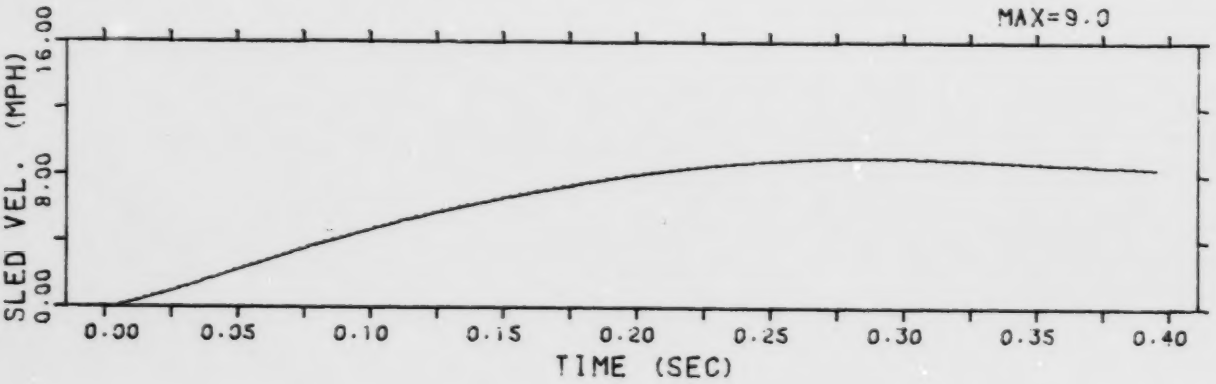
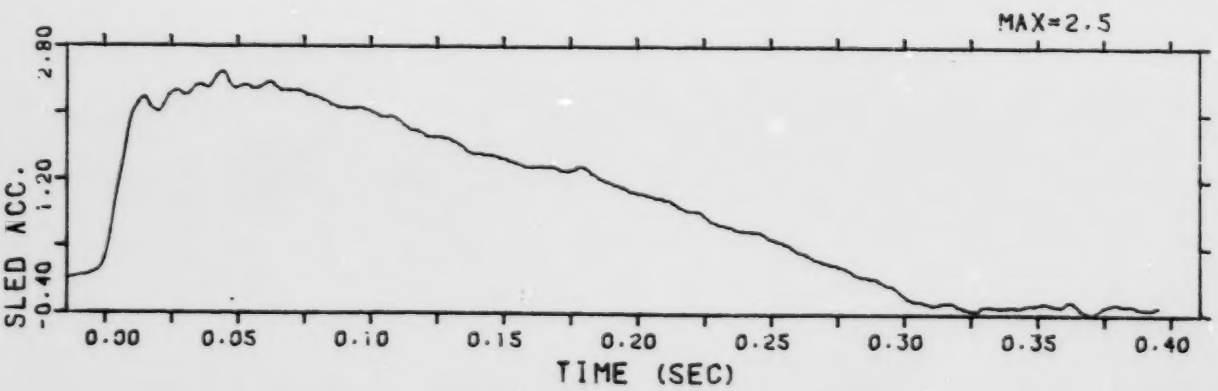
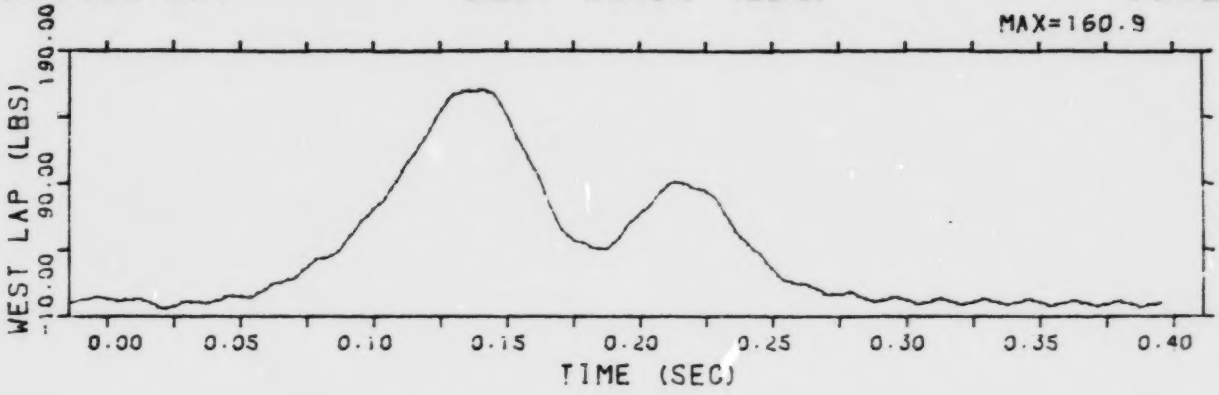
11:24:15





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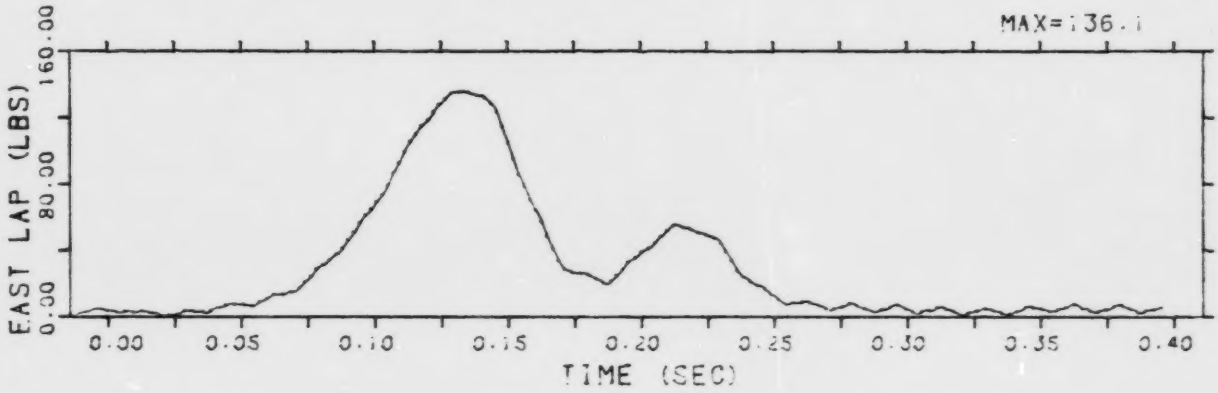
0.25
0.30
0.35
0.40
TIME (SEC)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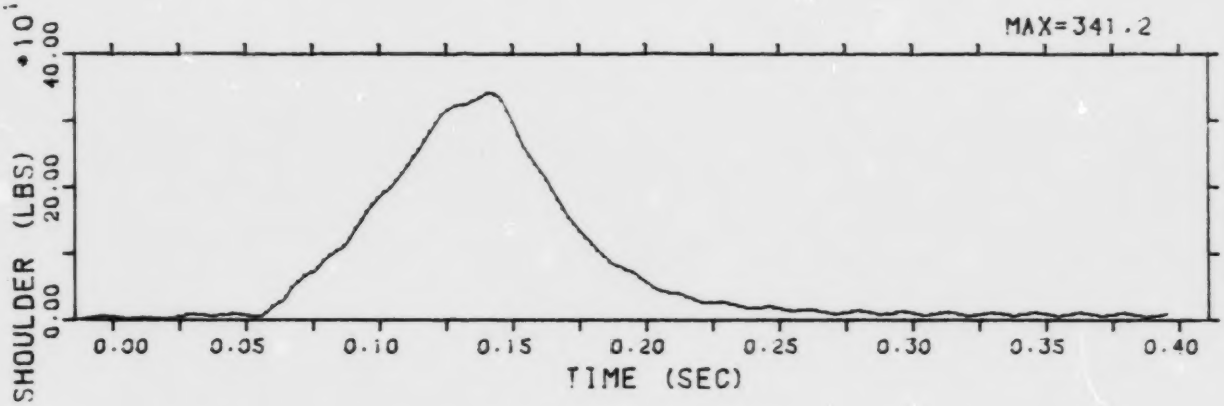
TIME (SEC)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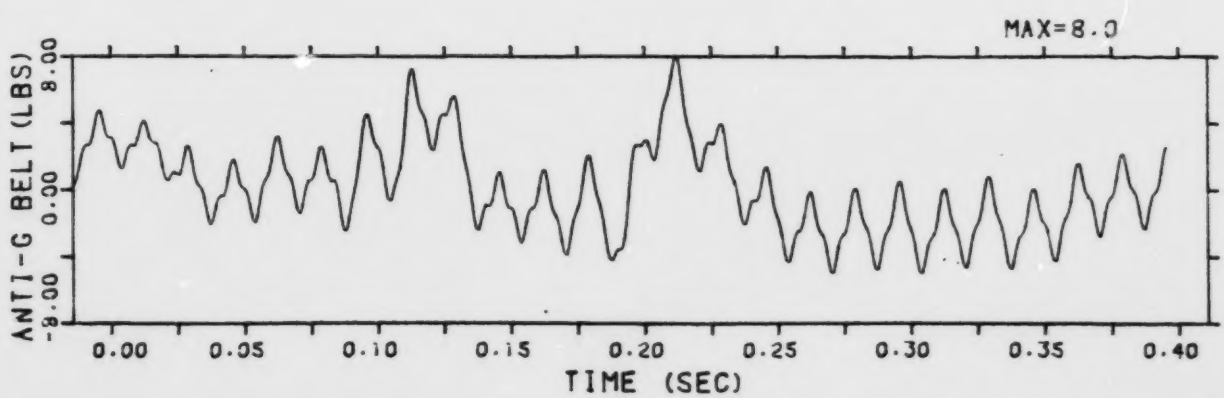
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)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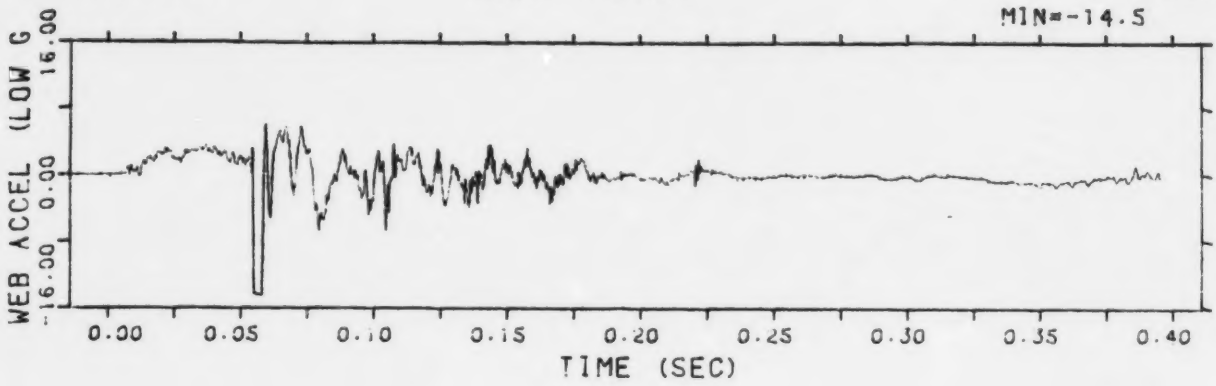
-8.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)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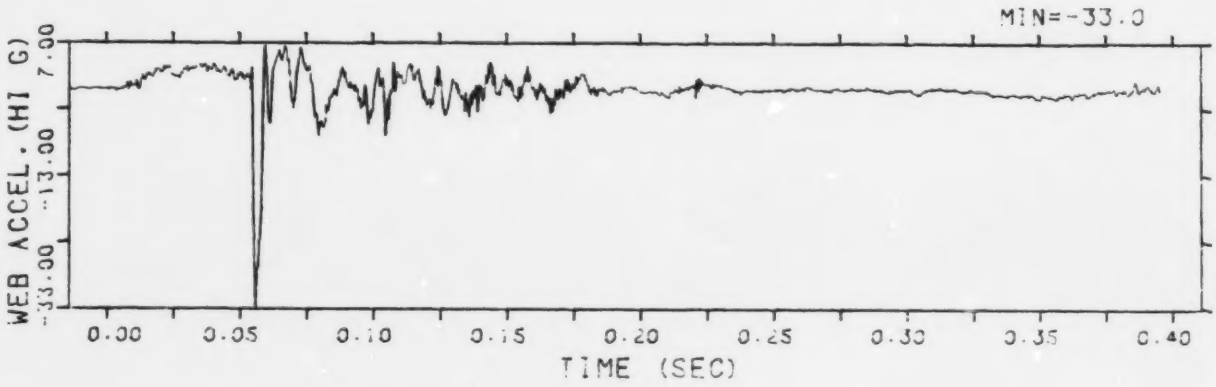
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)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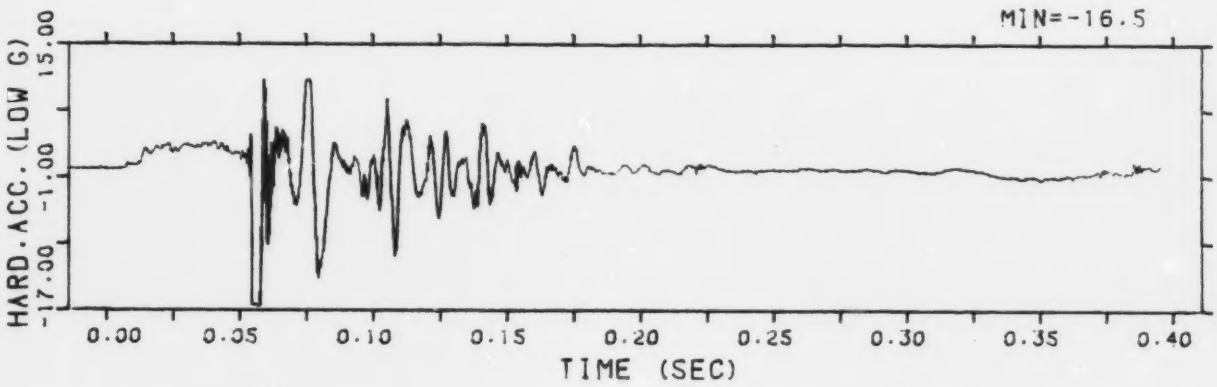
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)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0.15
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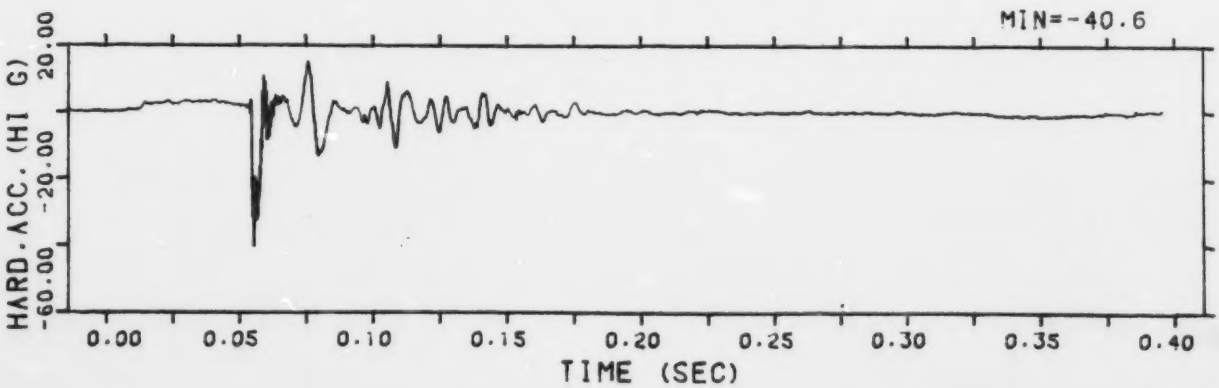
0.35
0.40
TIME (SEC)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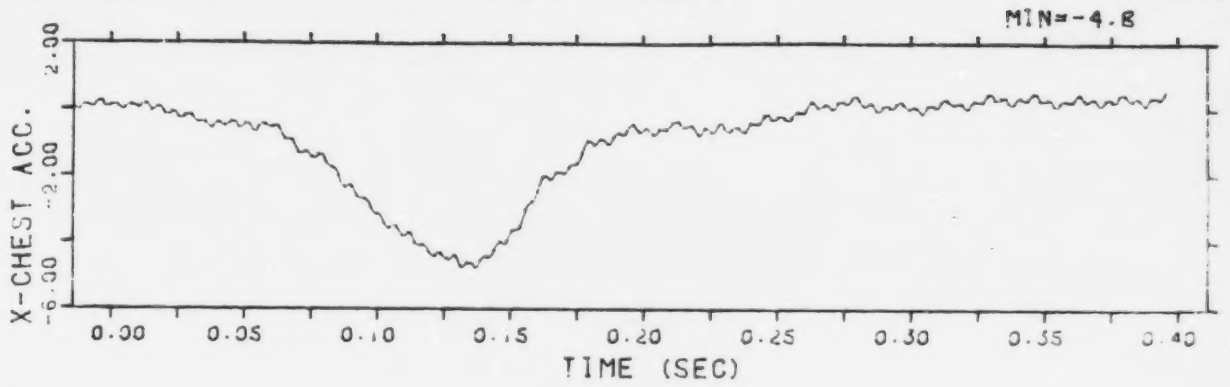
TIME (SEC)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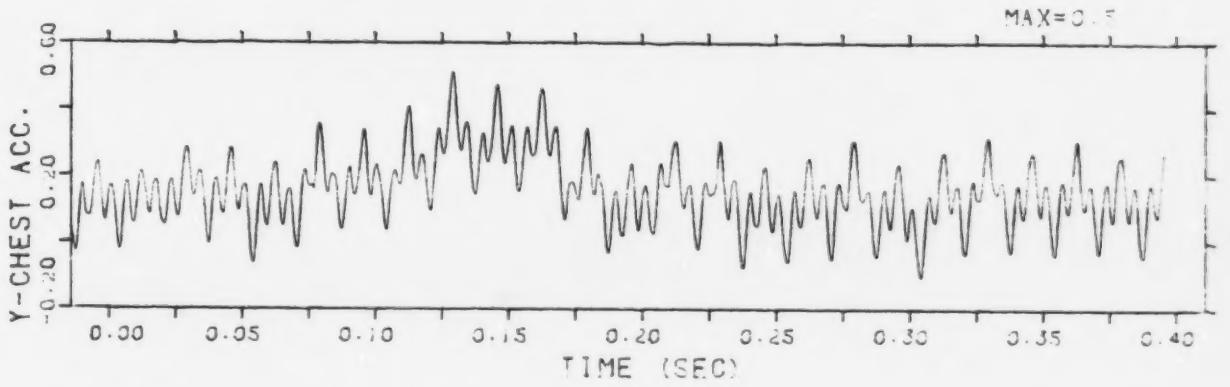
TIME (SEC)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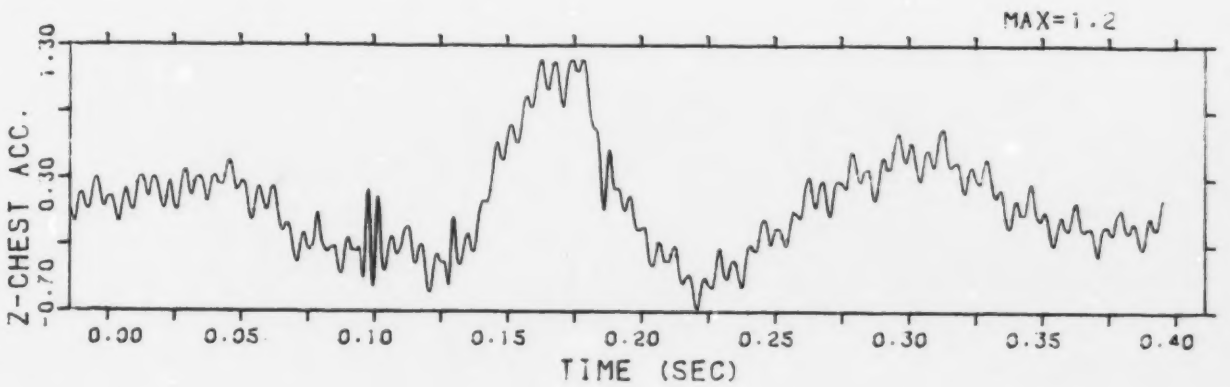
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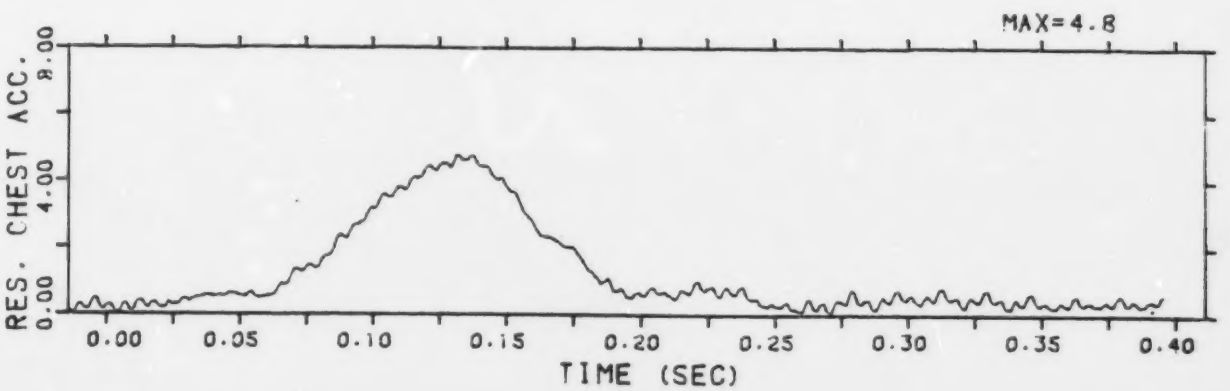
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0.00
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TIME (SEC)

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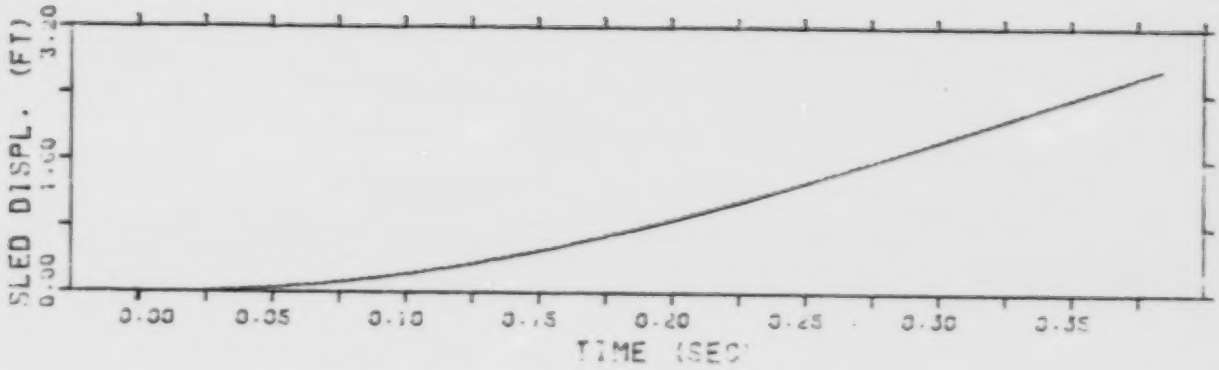
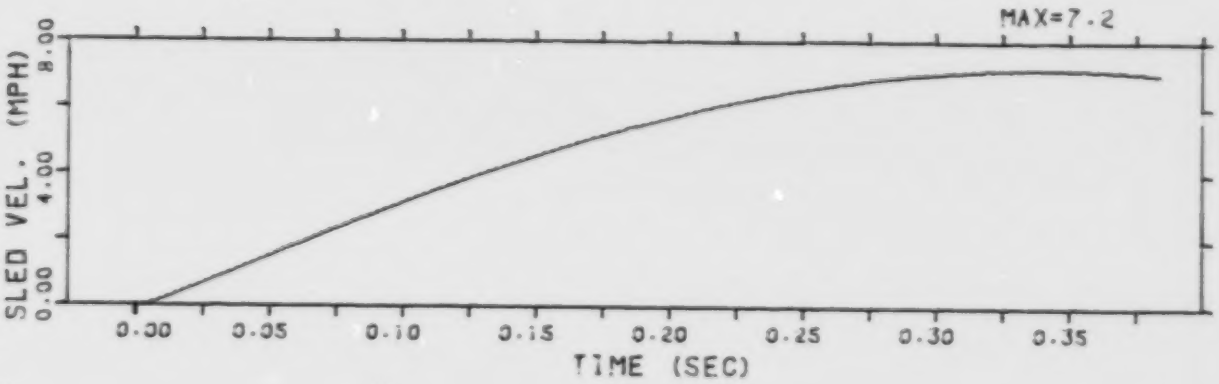
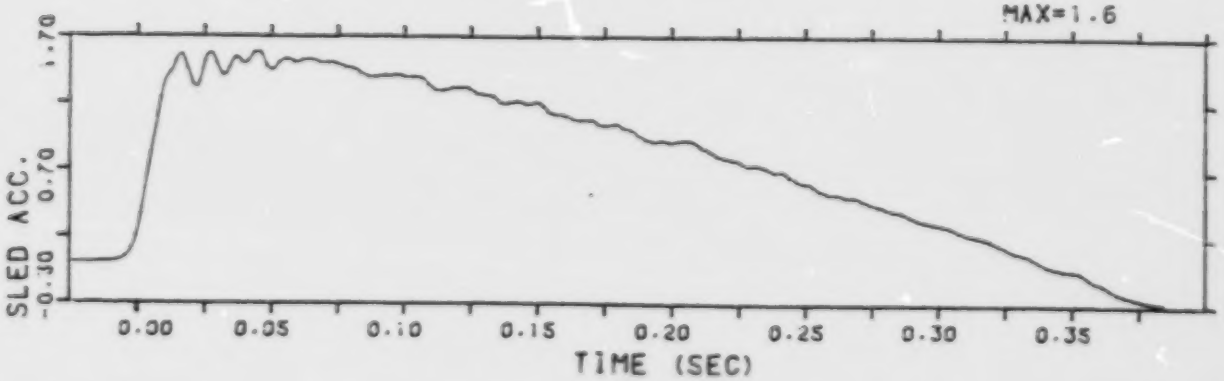
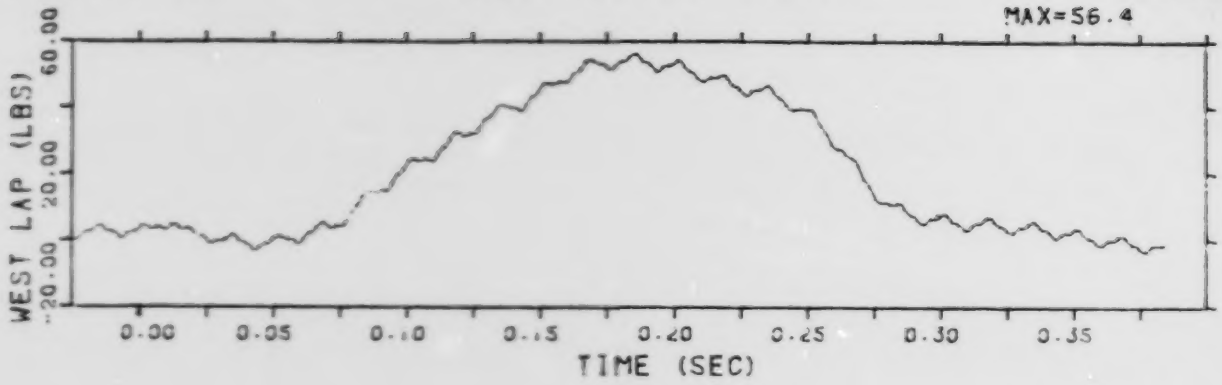
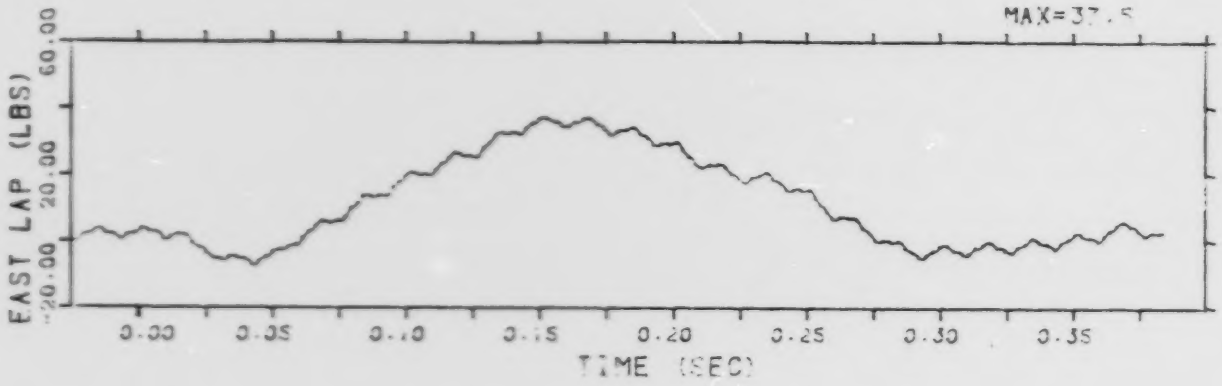
14:50:26

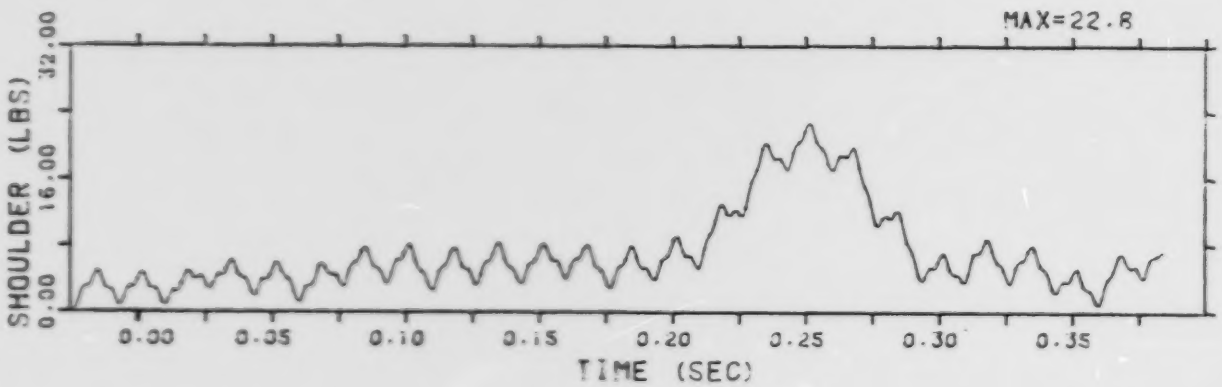


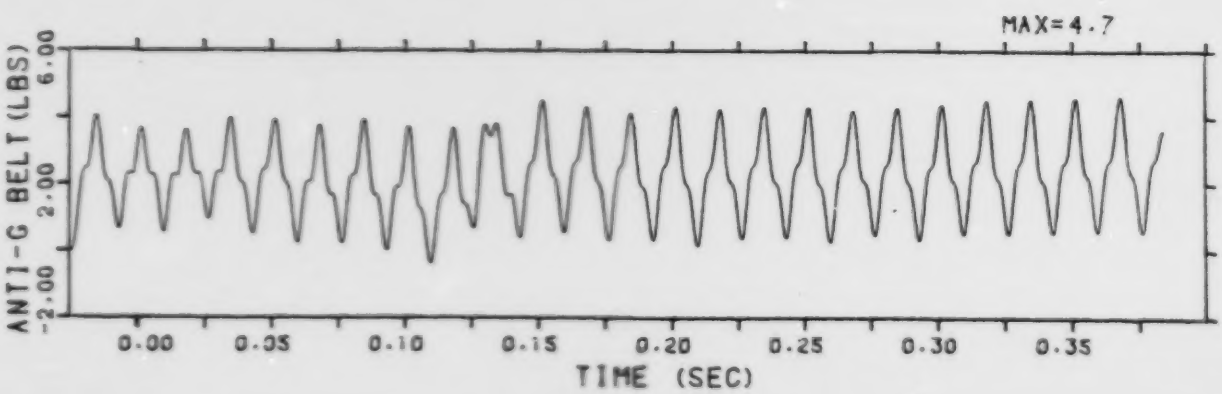


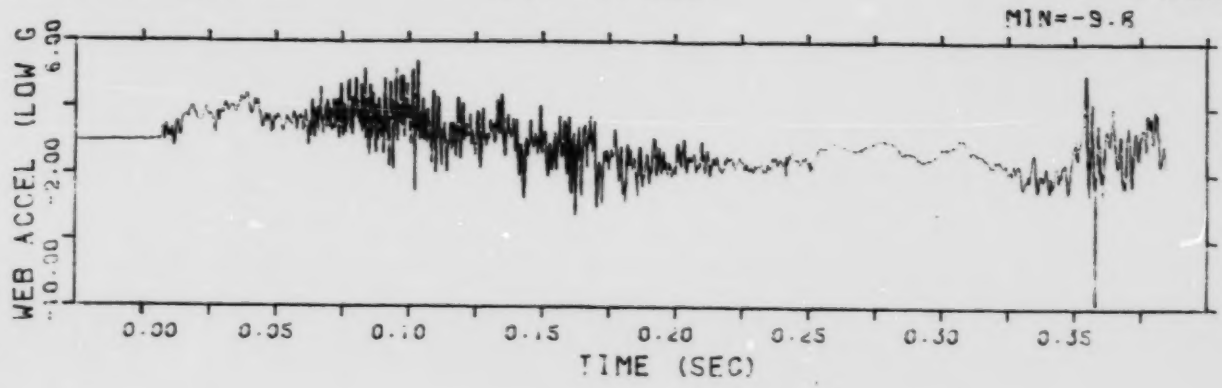


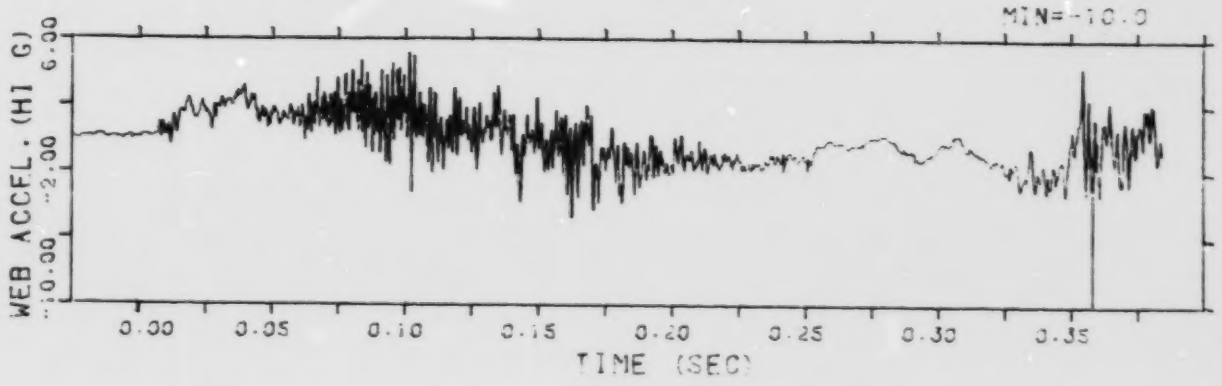

MAX=56.4
WEST LAP (LBS)
60.00
20.00
-20.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

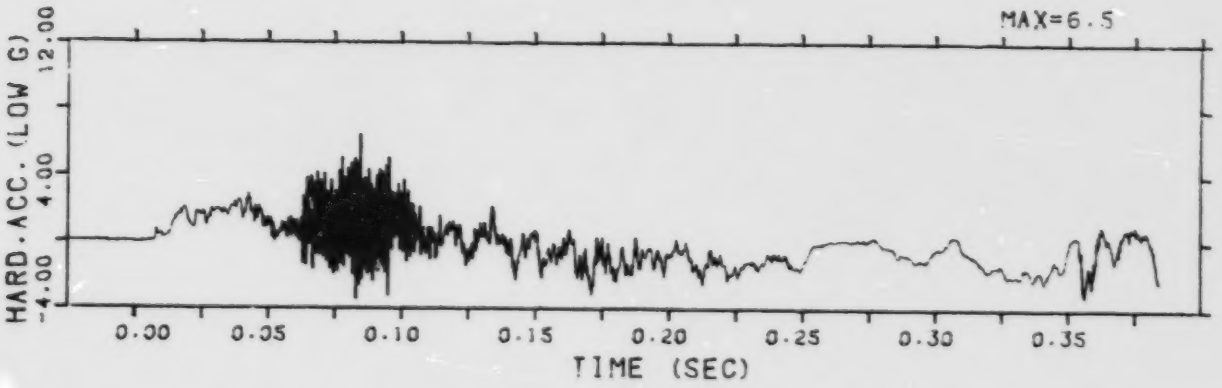

MAX=37.5
FAST LAP (LBS)
60.00
20.00
-20.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

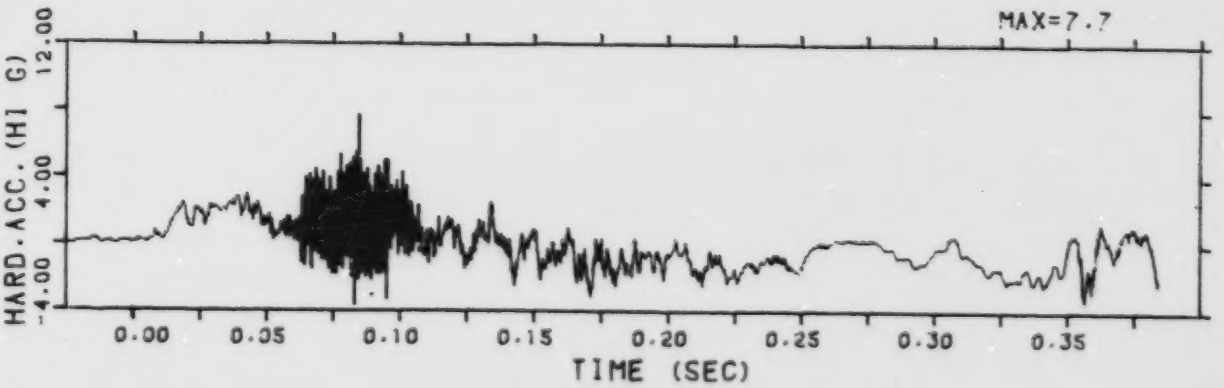

MAX=22.8
SHOULDER (LBS)
32.00
16.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

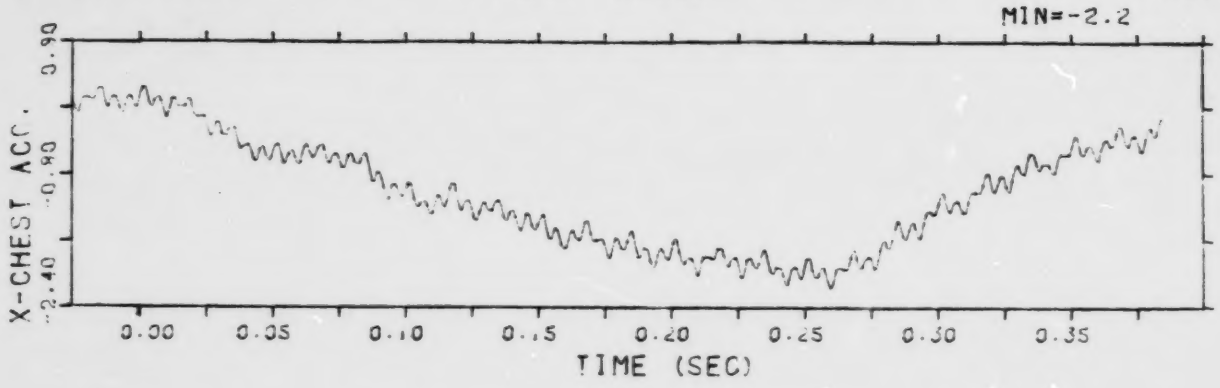

MAX=4.7
ANTI-G BELT (LBS)
6.00
2.00
-2.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

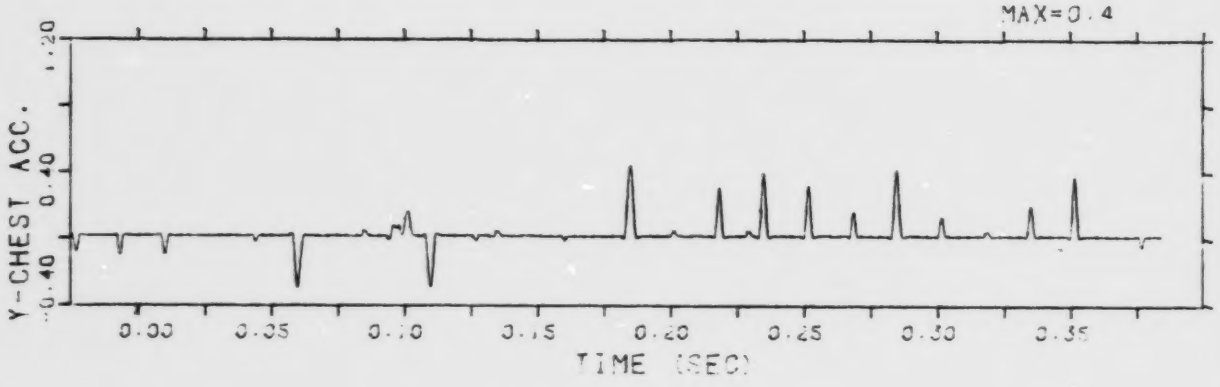

MIN=-9.8
WEB ACCEL (LOW G
6.00
-2.00
-10.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

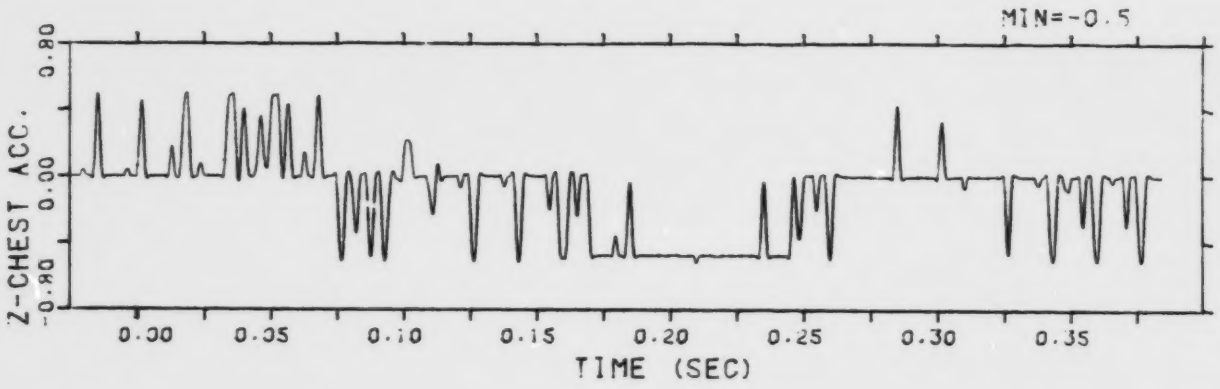

MIN=-10.0
WEB ACCEL. (HI G)
6.00
-2.00
-10.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

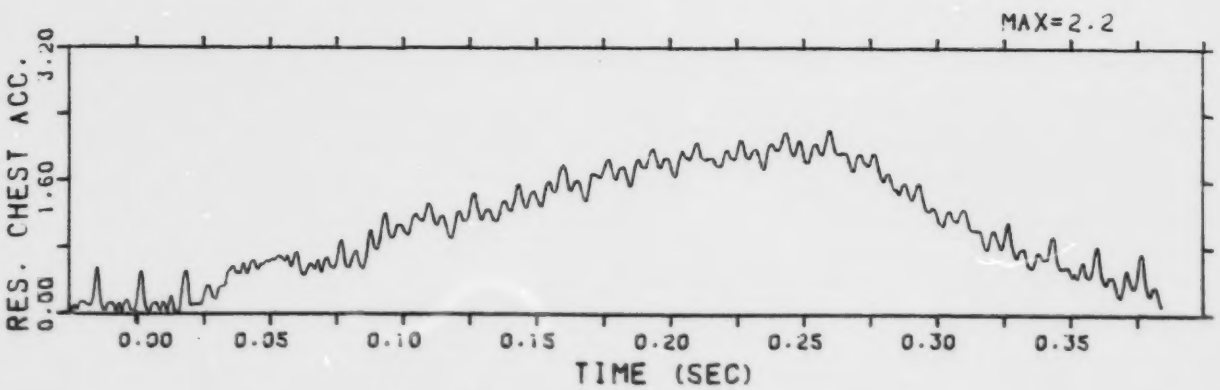

MAX=6.5
HARD.ACC. (LOW G)
12.00
4.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=7.7
HARD.ACC. (HI G)
12.00
4.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-2.2
X-CHEST ACC.
0.90
-0.90
-2.40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=0.4
Y-CHEST ACC.
1.20
0.40
-0.40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-0.5
Z-CHEST ACC.
0.80
0.00
-0.80
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=2.2
RES. CHEST ACC.
3.20
1.60
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

DK:DFS470.DAT

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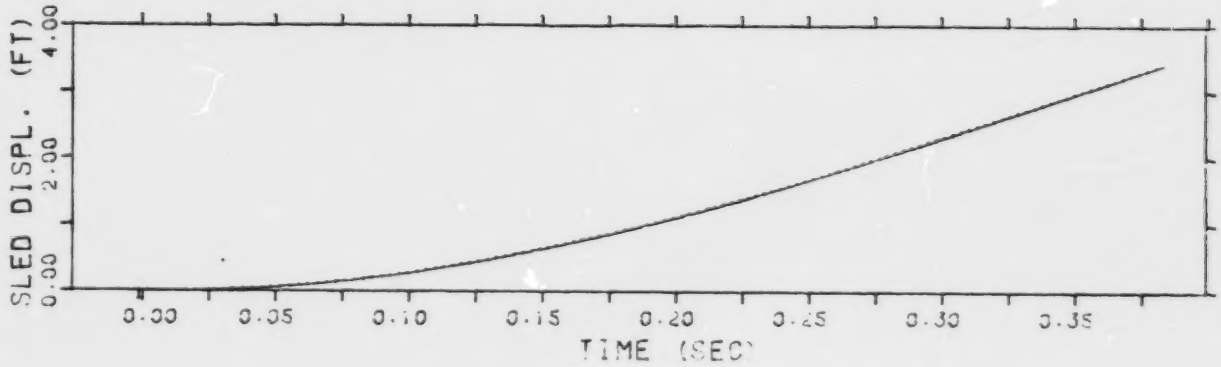
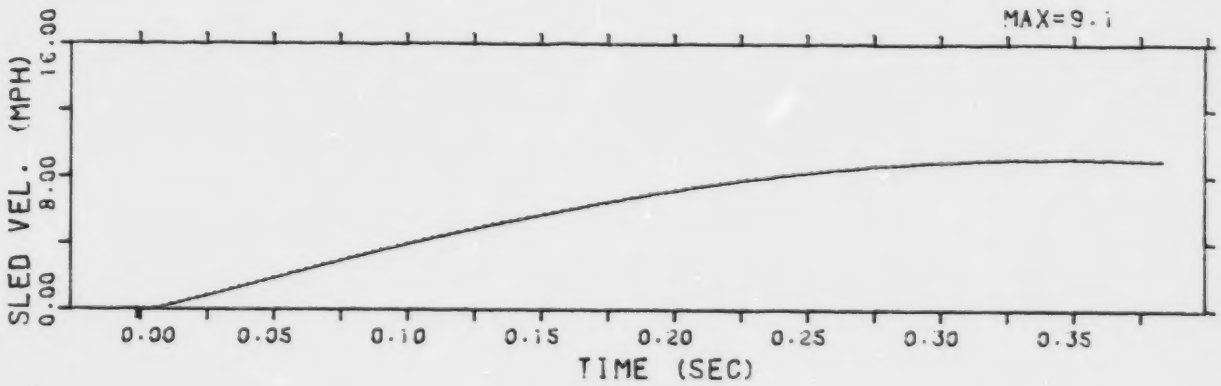
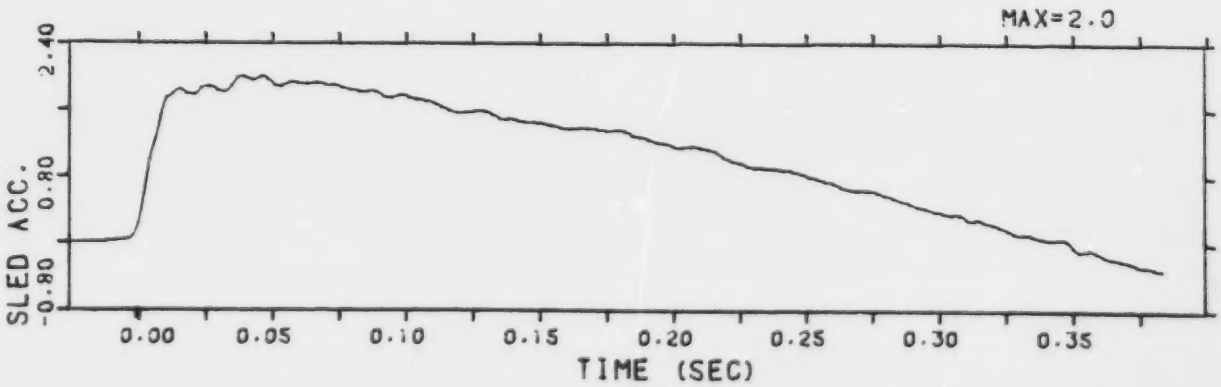
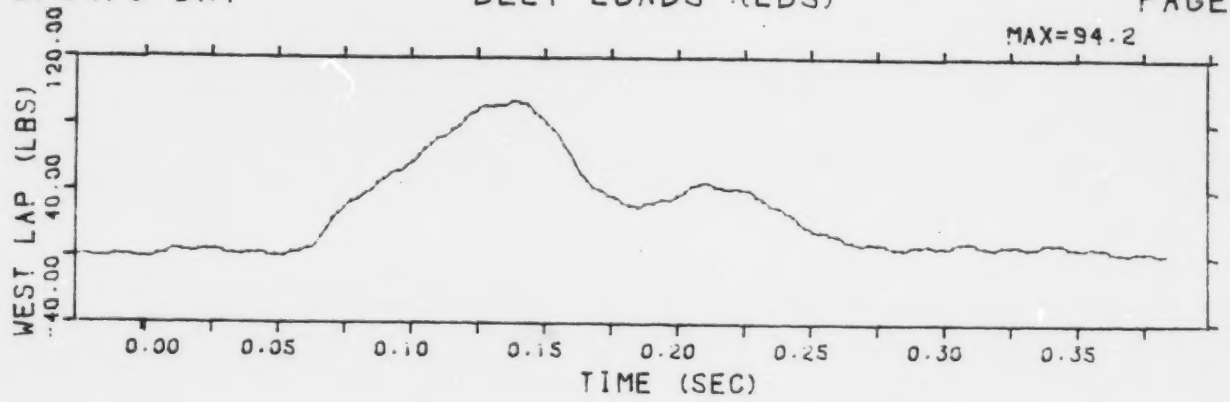
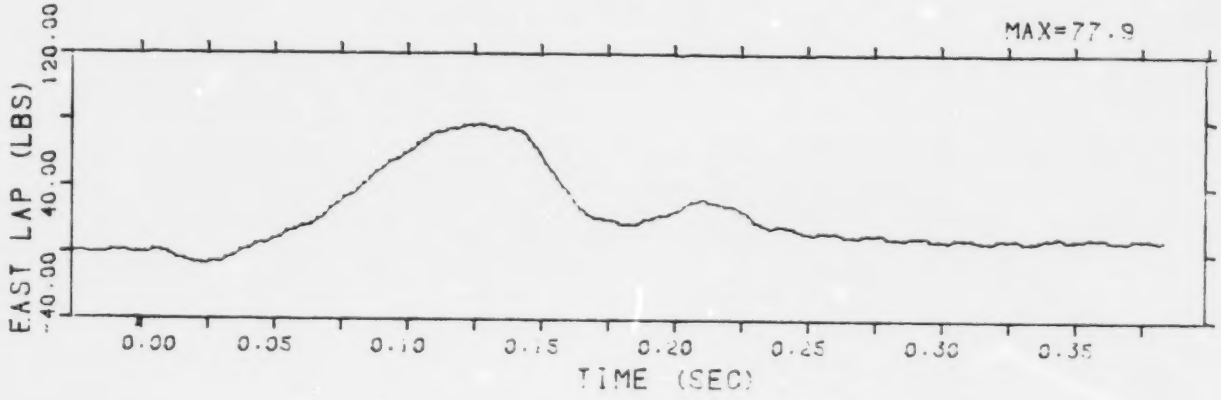
09:11:34

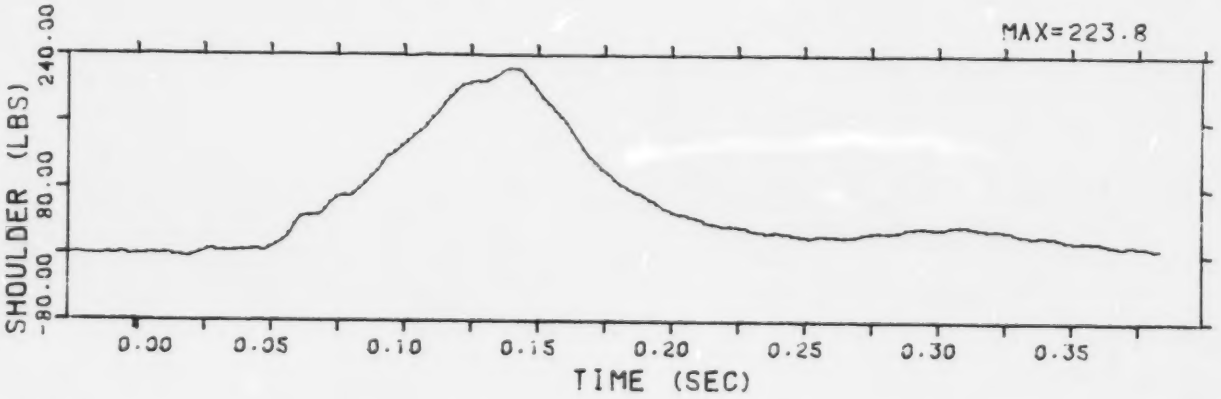


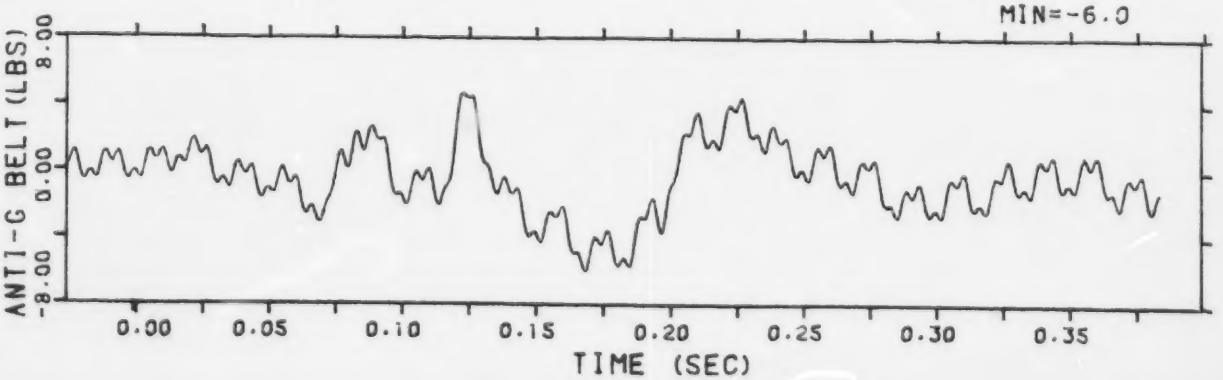


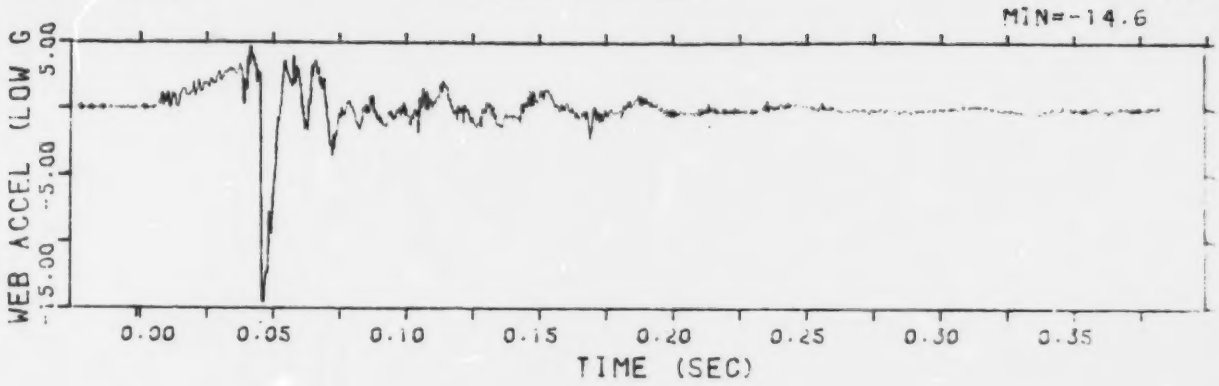


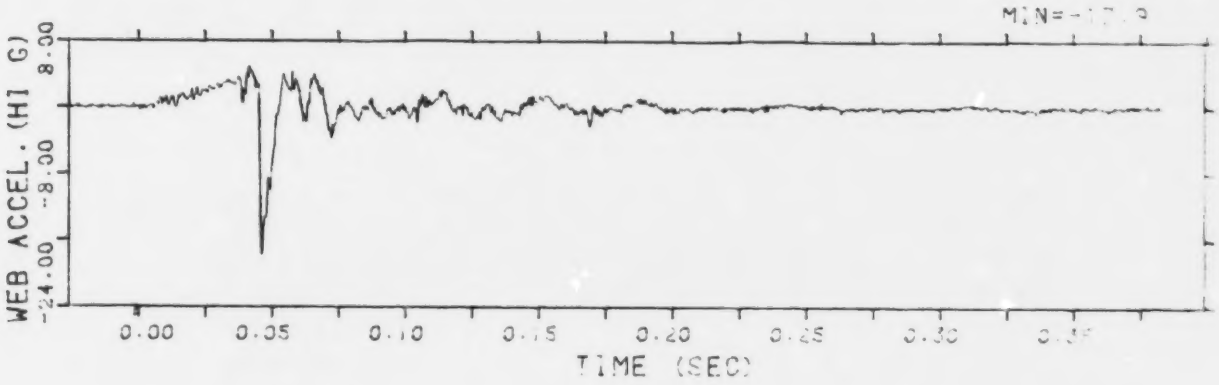

MAX=94.2
WEST LAP (LBS)
120.00
40.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

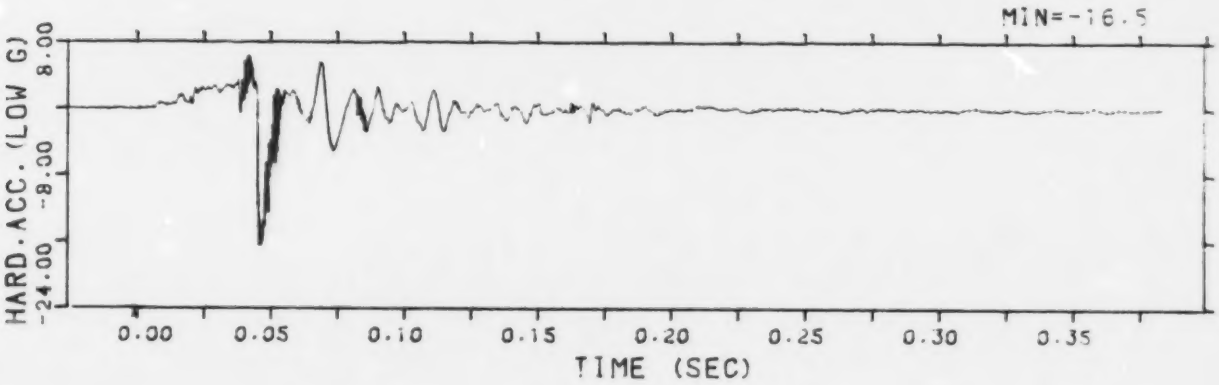

MAX=77.9
EAST LAP (LBS)
120.00
40.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

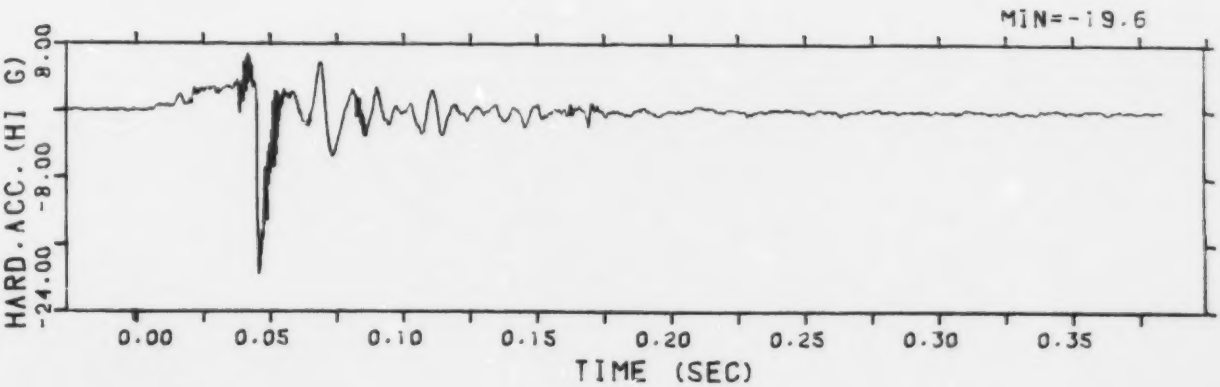

MAX=223.8
SHOULDER (LBS)
240.00
80.00
-80.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

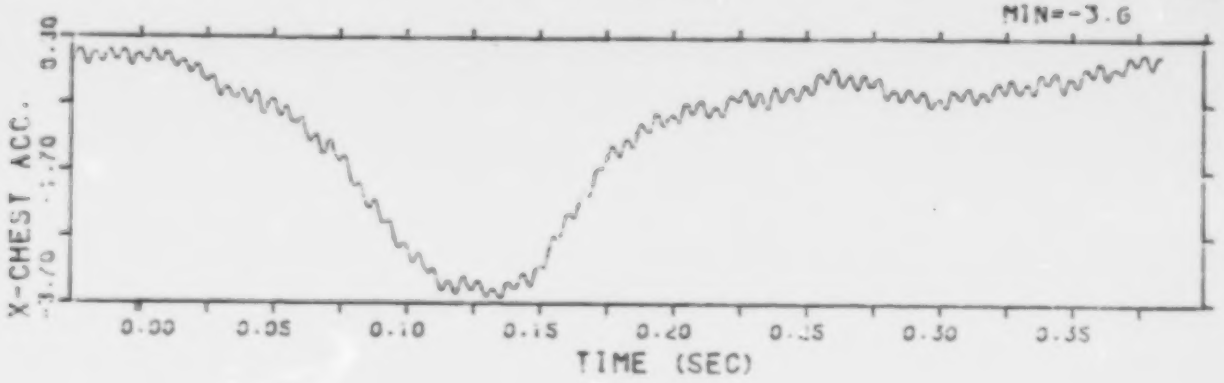

MIN=-6.0
ANTI-G BELT (LBS)
8.00
0.00
-8.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

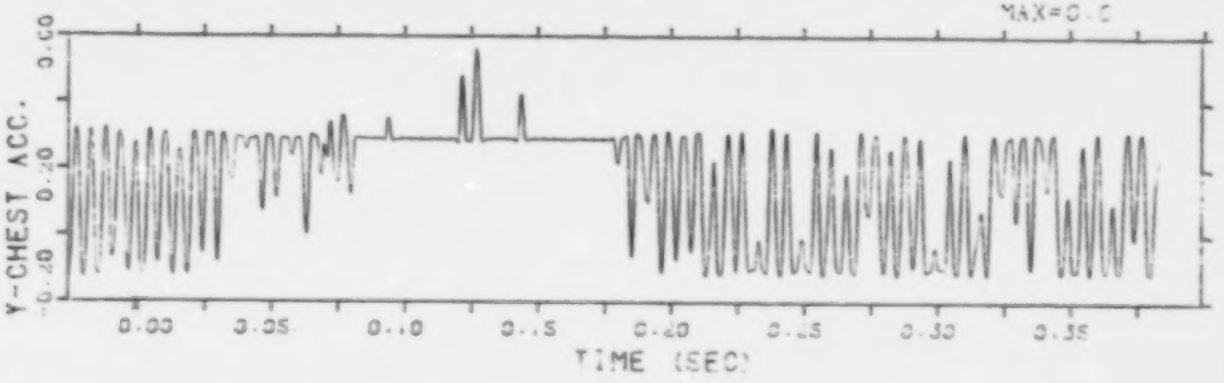

MIN=-14.6
WEB ACCEL (LOW G
5.00
-5.00
-15.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

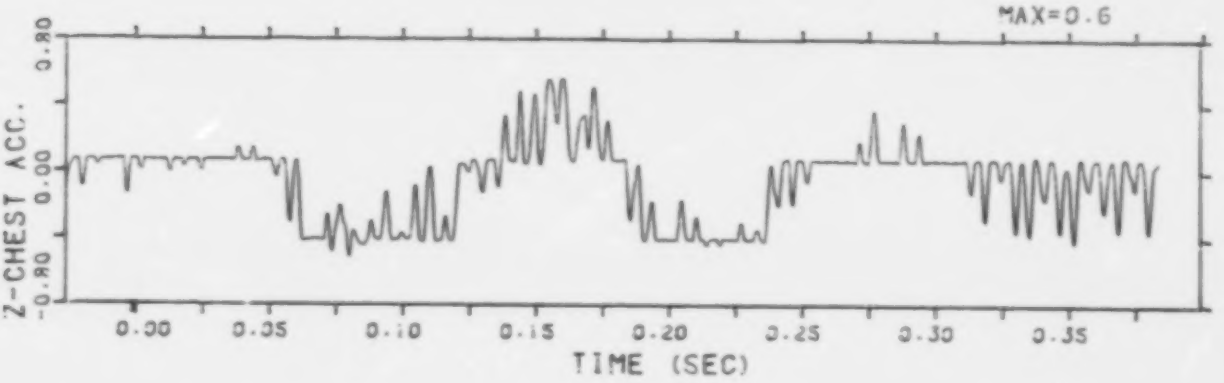

WEB ACCEL. (HI G)
8.00
-8.00
-24.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
TIME (SEC)

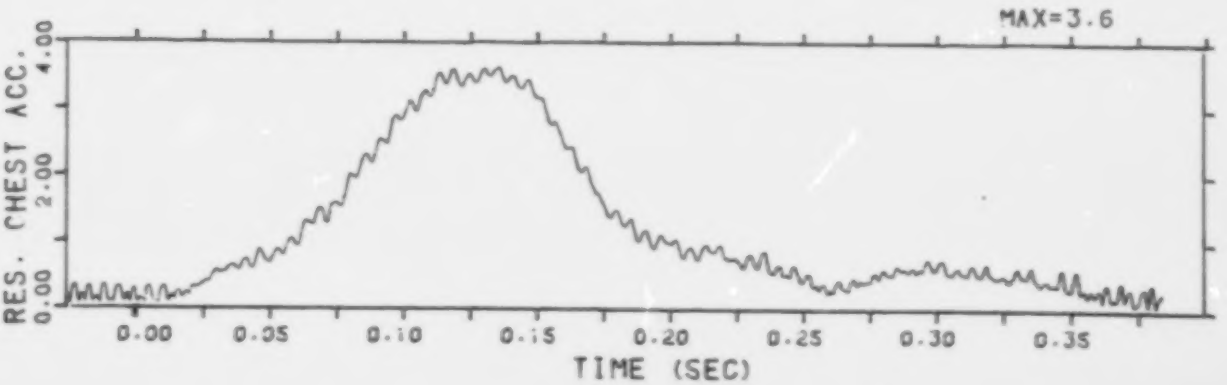

MIN=-16.5
HARD.ACC. (LOW G)
8.00
-8.00
-24.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-19.6
HARD.ACC. (HI G)
8.00
-8.00
-24.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-3.6
X-CHEST ACC.
0.35
-3.70
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=0.6
Y-CHEST ACC.
0.60
0.20
-0.40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=0.6
Z-CHEST ACC.
0.80
0.00
-0.80
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=3.6
RES. CHEST ACC.
4.00
2.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

DK:DFS471.DAT

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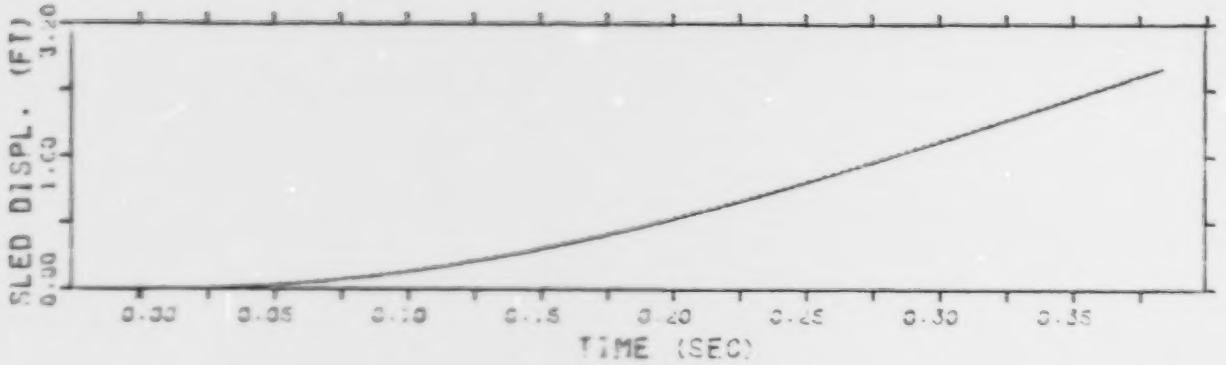
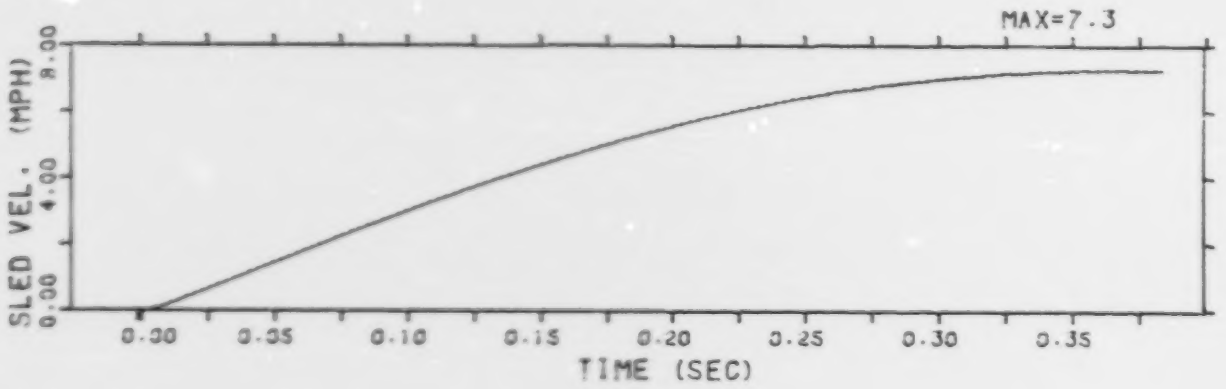
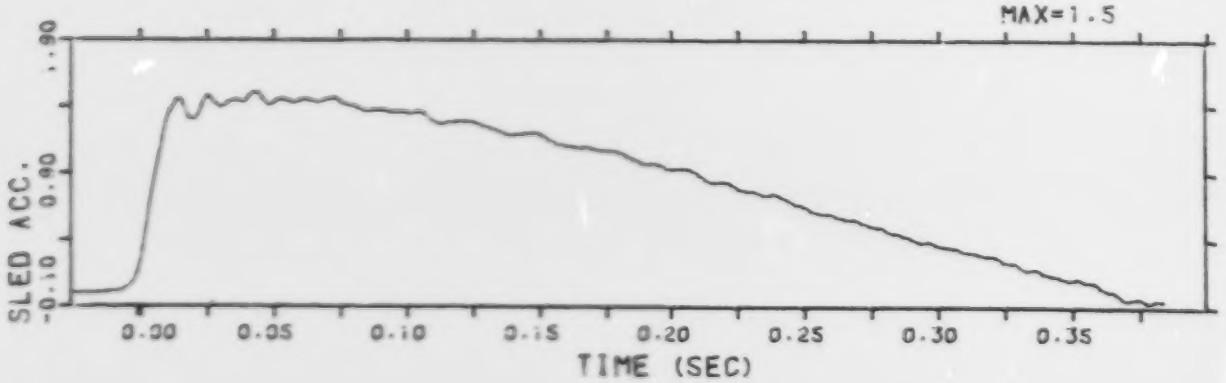
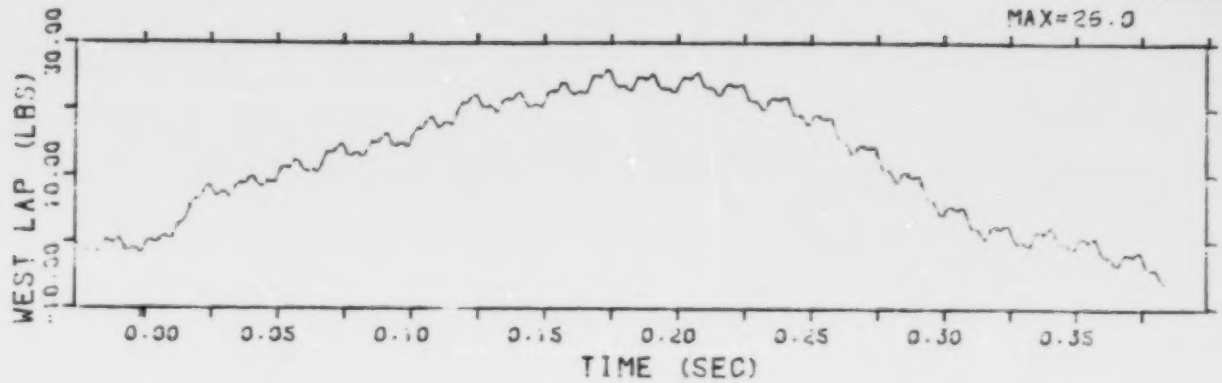
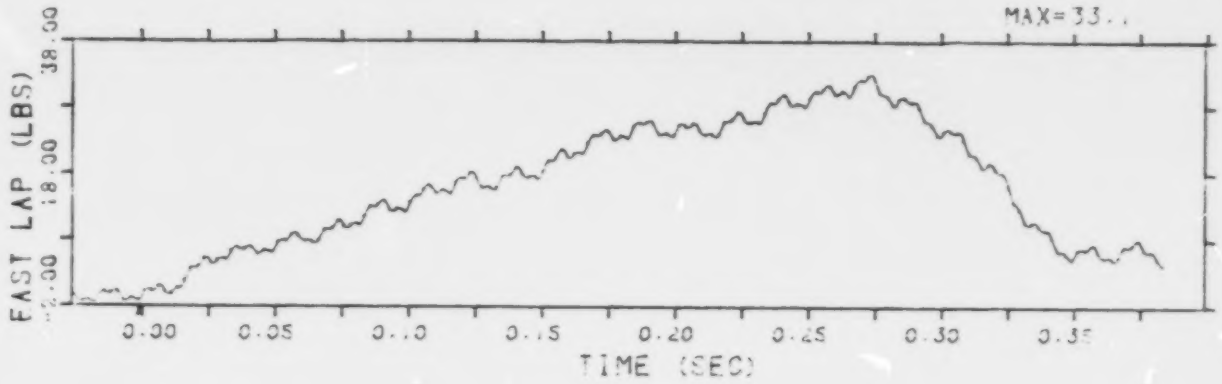
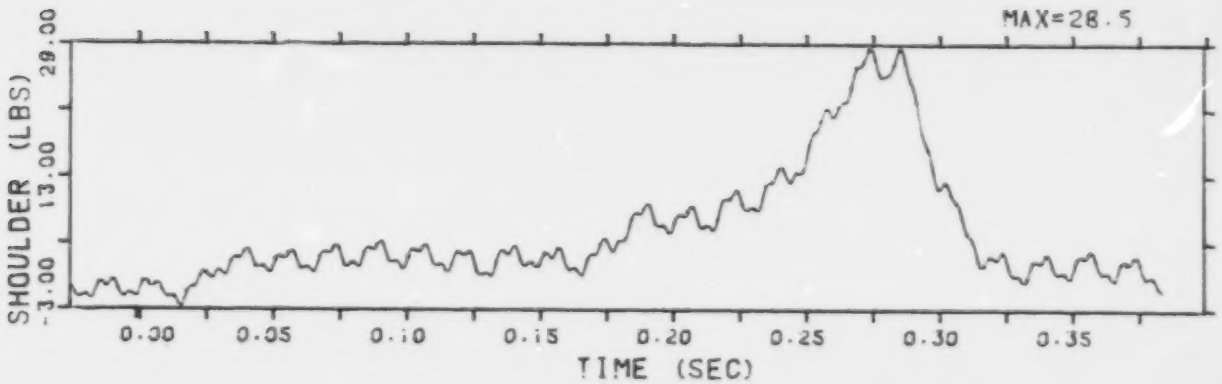


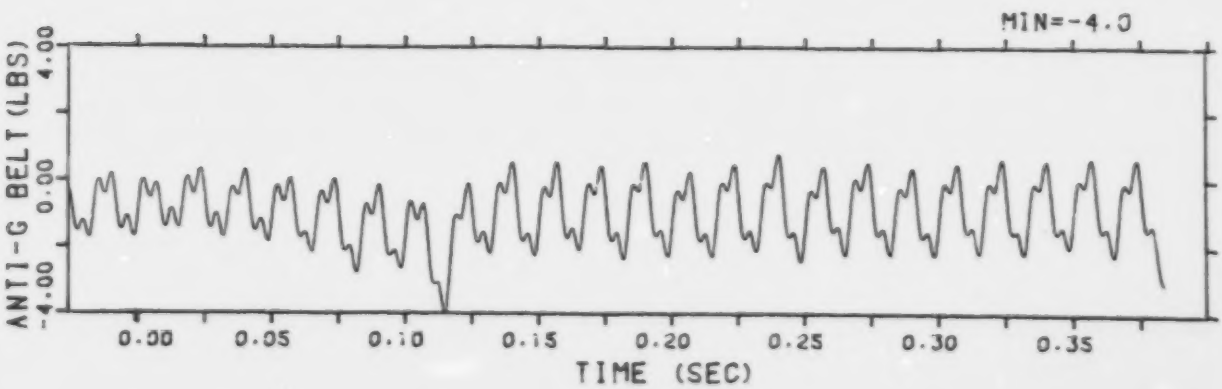


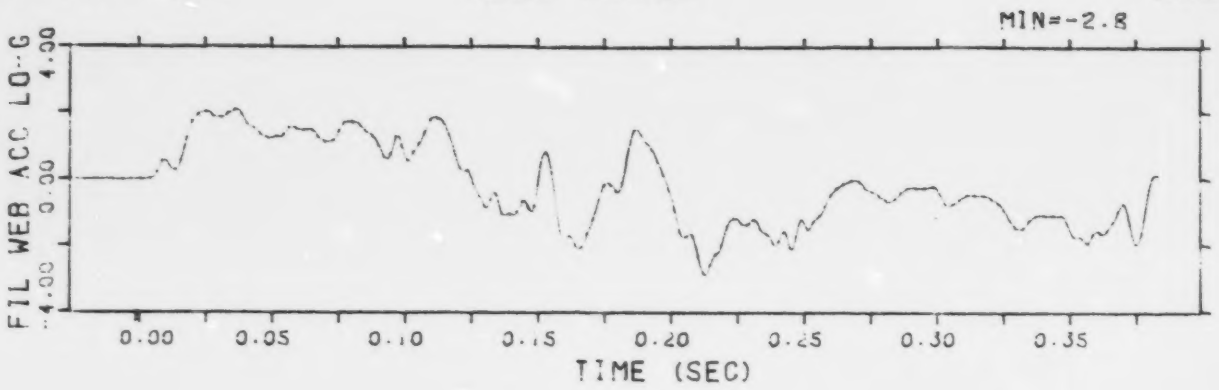


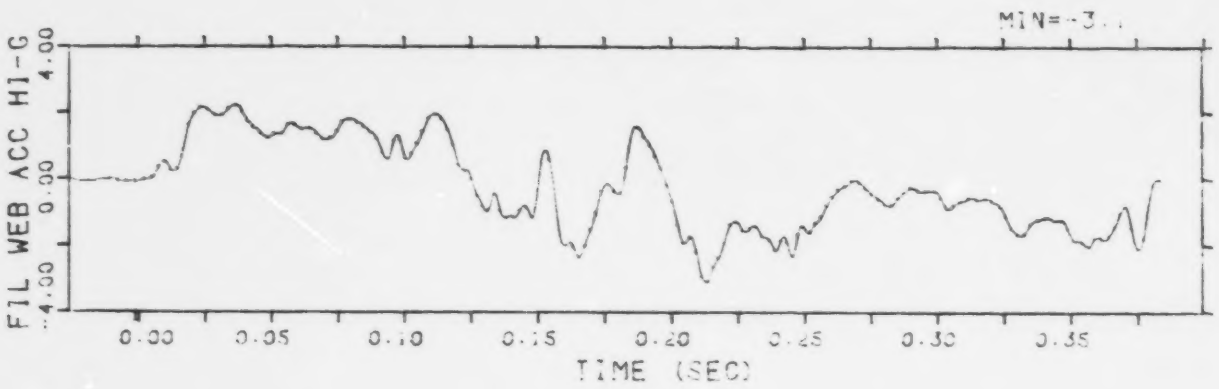

MAX=25.0
WEST LAP (LBS)
30.00
10.00
-10.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

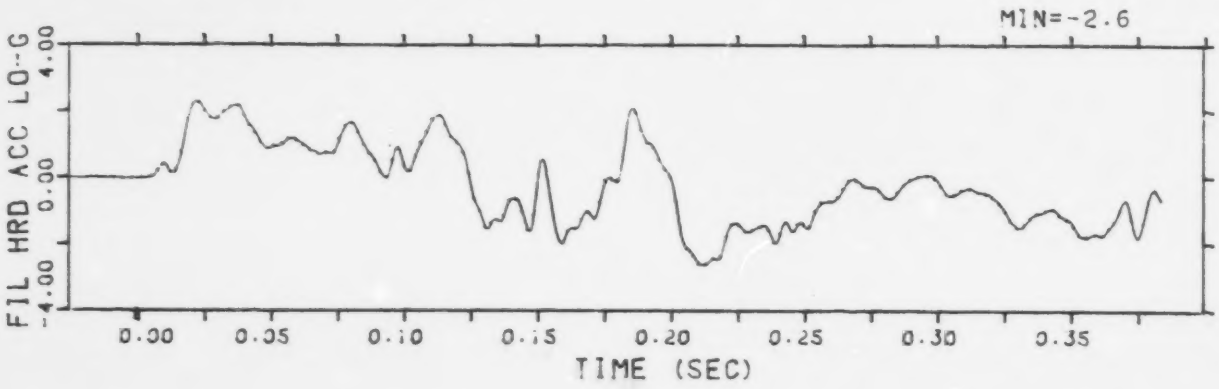

MAX=33.1
FAST LAP (LBS)
38.00
18.00
-2.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

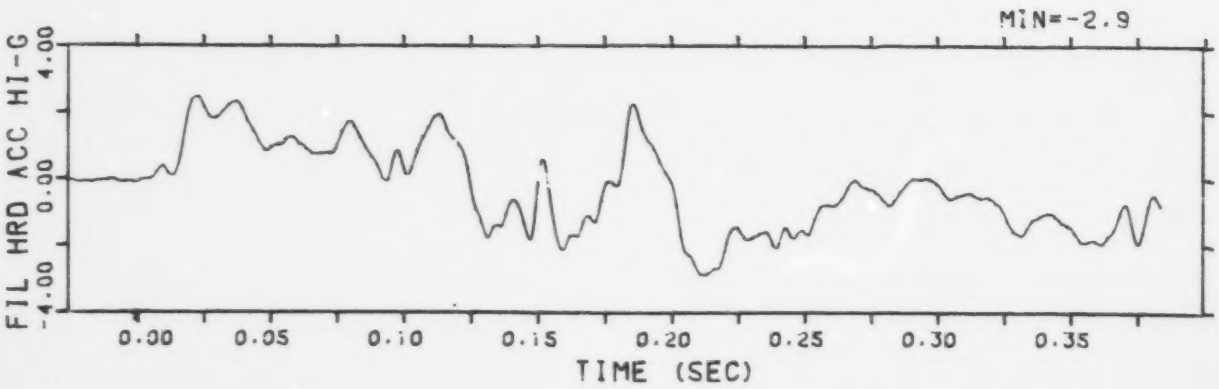

MAX=28.5
SHOULDER (LBS)
29.00
13.00
-3.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

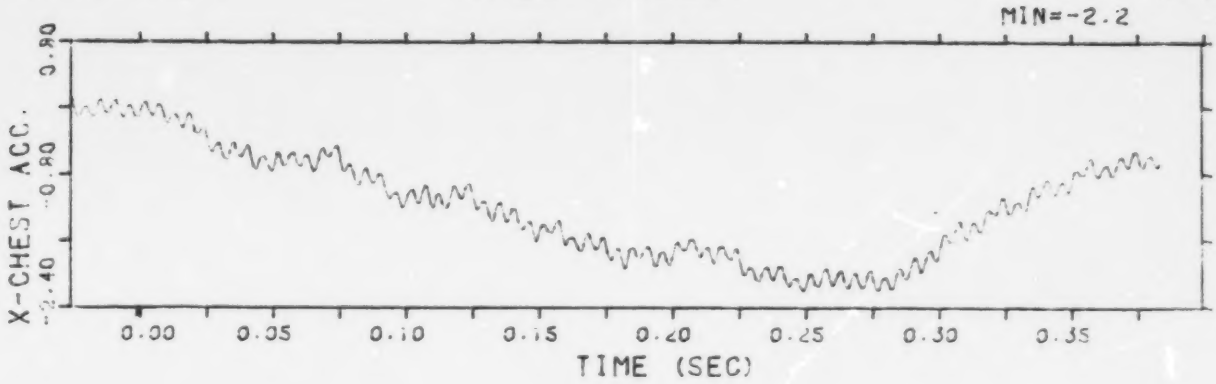

MIN=-4.0
ANTI-G BELT (LBS)
4.00
0.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

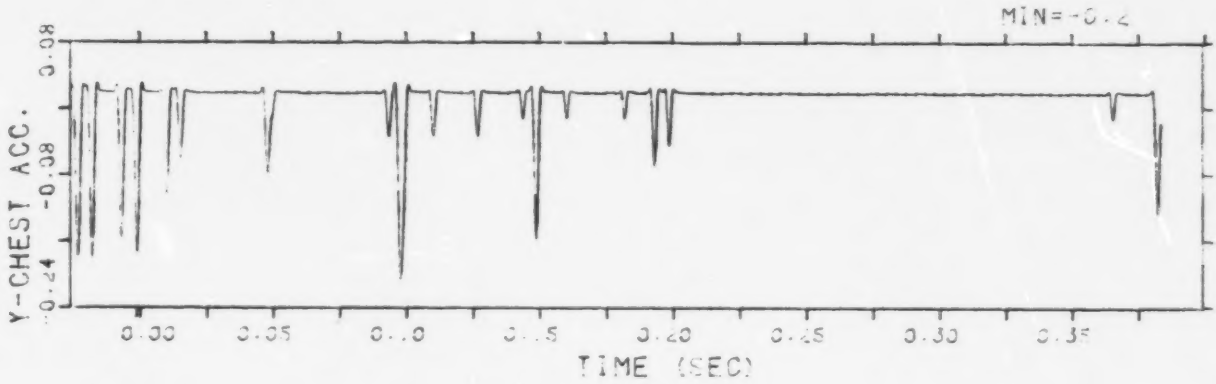

MIN=-2.8
FIL WEB ACC LO-G
4.00
0.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

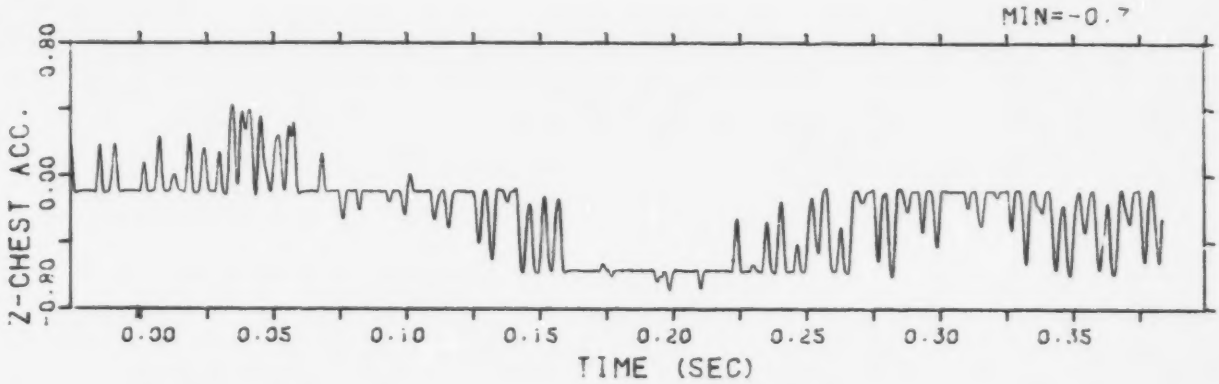

MIN=-3.1
FIL WEB ACC HI-G
4.00
0.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

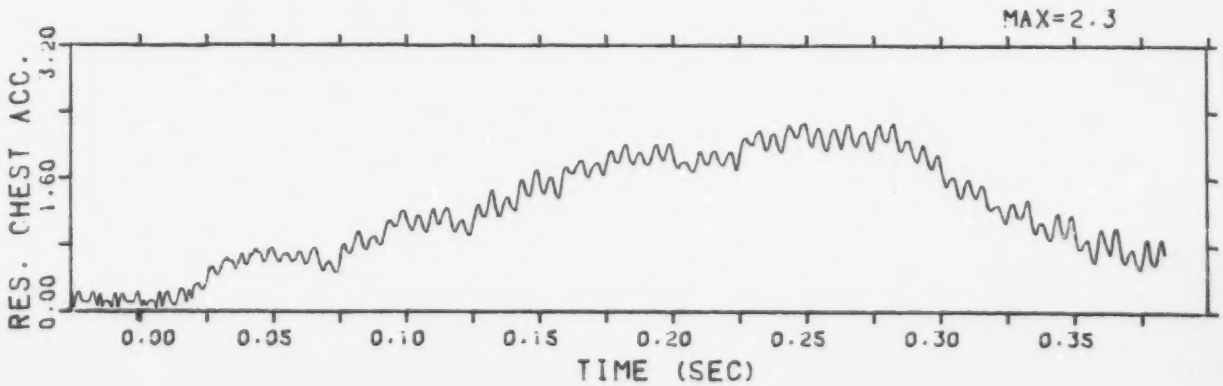

MIN=-2.6
FIL HRD ACC LO-G
4.00
0.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-2.9
FIL HRD ACC HI-G
4.00
0.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-2.2
X-CHEST ACC.
0.80
-0.80
-2.40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-0.4
Y-CHEST ACC.
0.38
-0.38
-0.24
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-0.7
Z-CHEST ACC.
0.80
0.00
-0.80
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=2.3
RES. CHEST ACC.
3.20
1.60
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

DOIEM IMPACT STUDIES FACILITY

DK:DF_4,2.DAT

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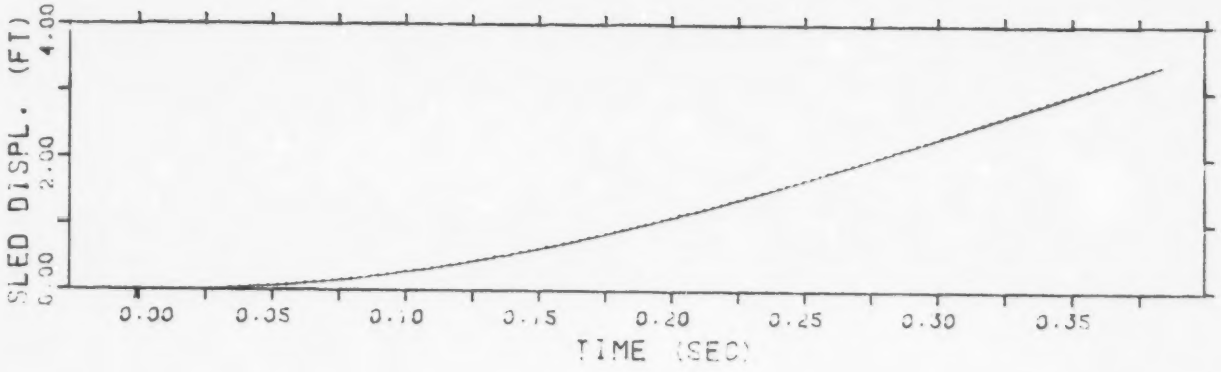
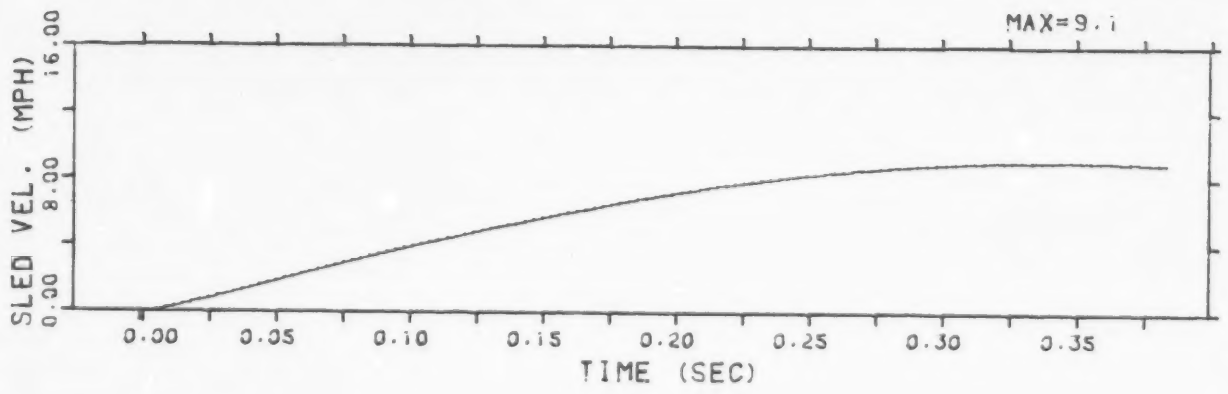
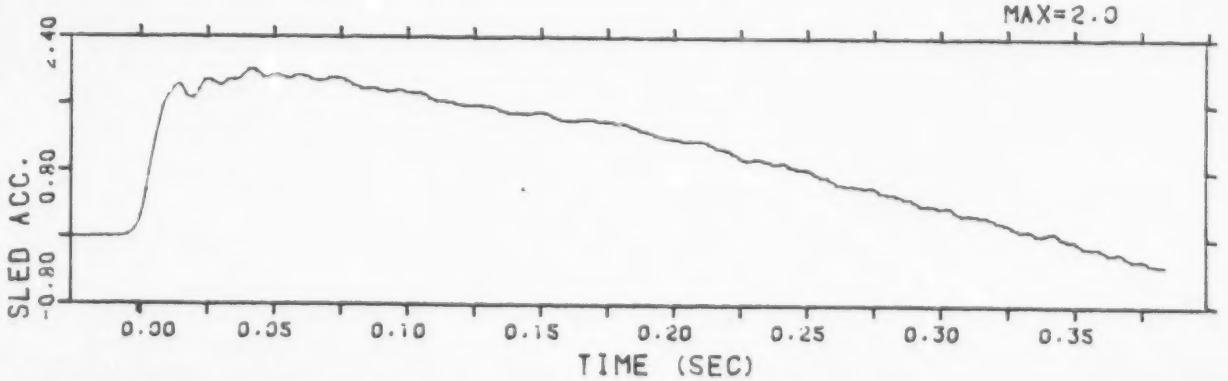
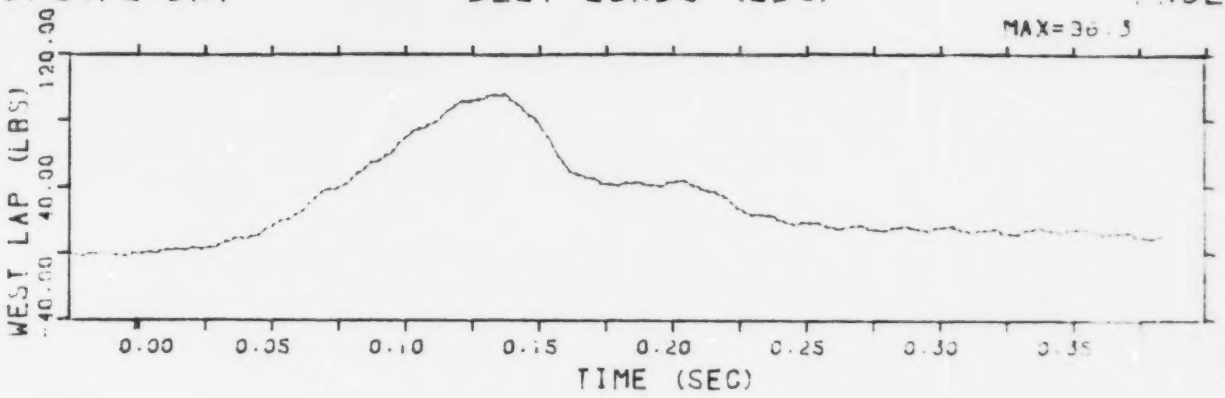
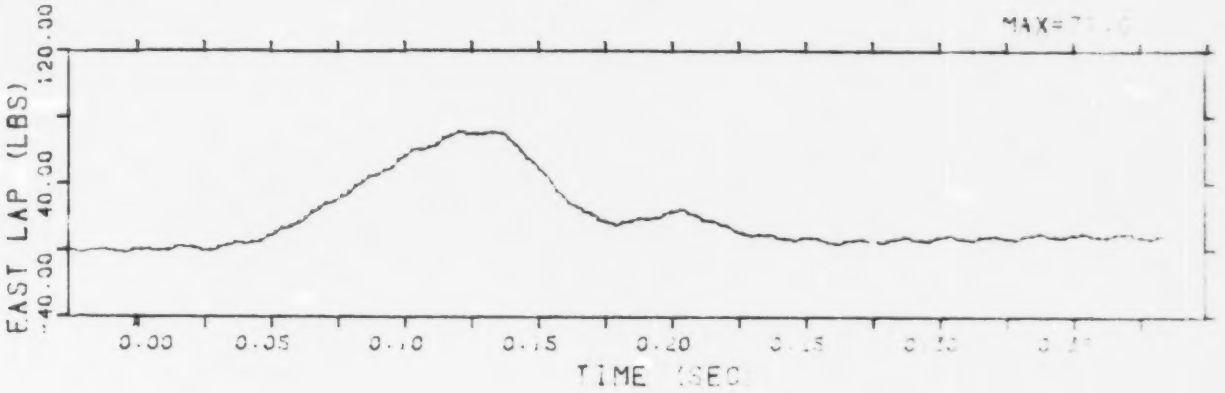
14:14:47

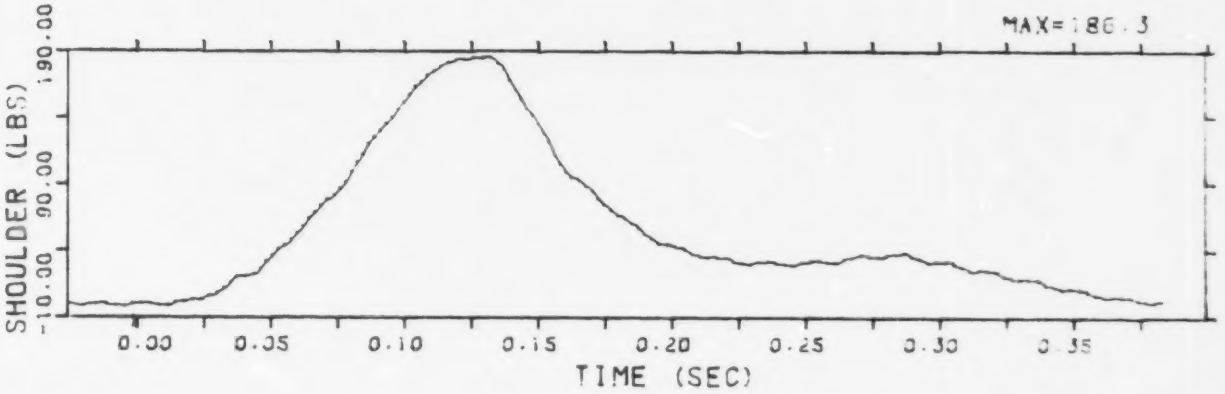


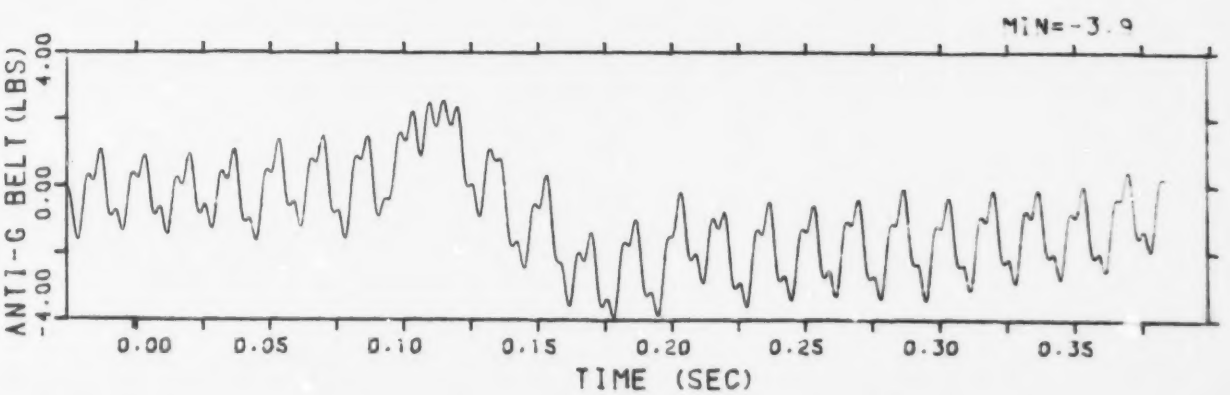


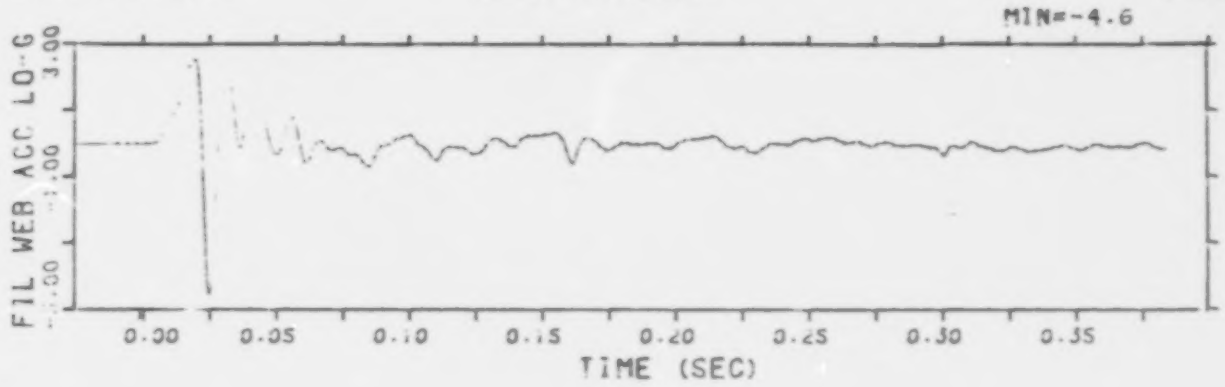


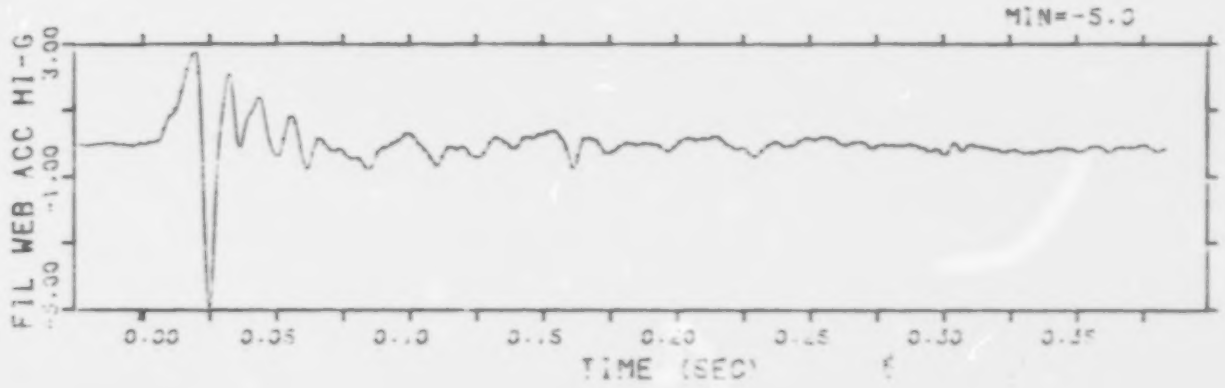

MAX=36.5
WEST LAP (LBS)
120.00
40.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

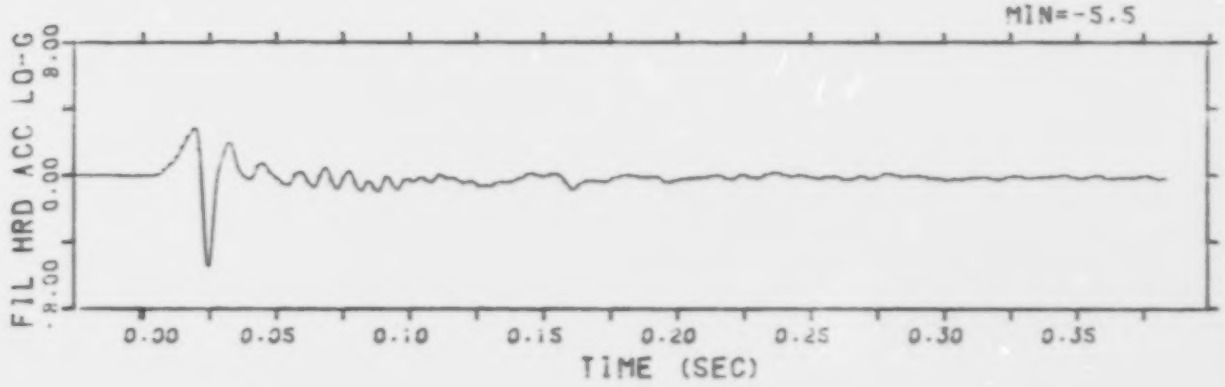

MAX=
EAST LAP (LBS)
120.00
40.00
-40.00
0.00
0.05
0.10
0.15
0.20
TIME (SEC)

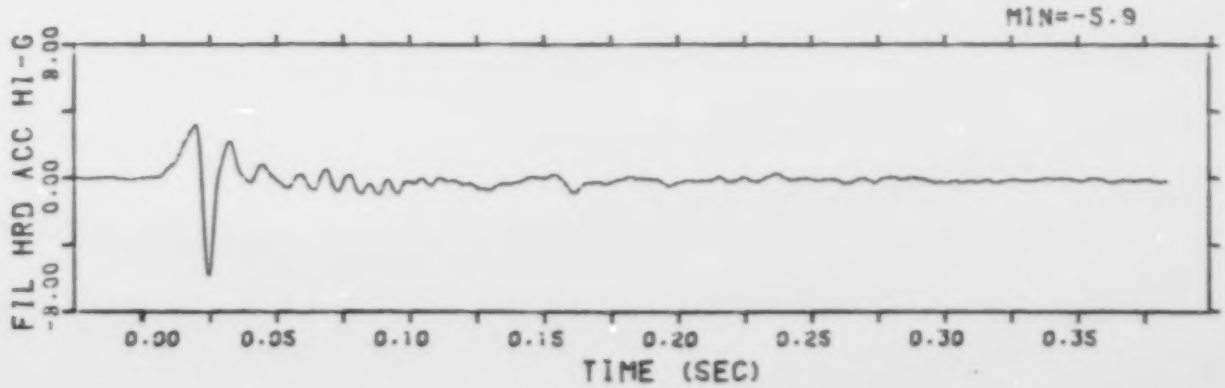

MAX=180.3
SHOULDER (LBS)
190.00
90.00
-10.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

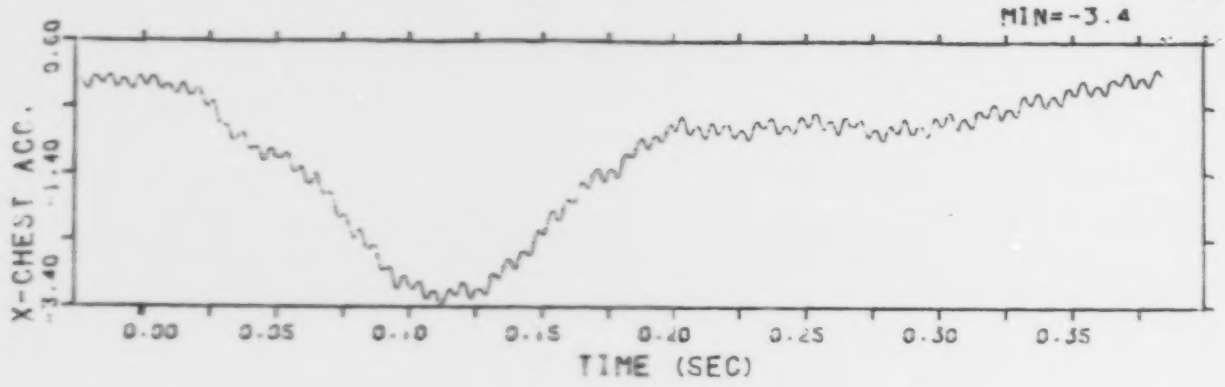

MIN=-3.9
ANTI-G BELT (LBS)
4.00
0.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

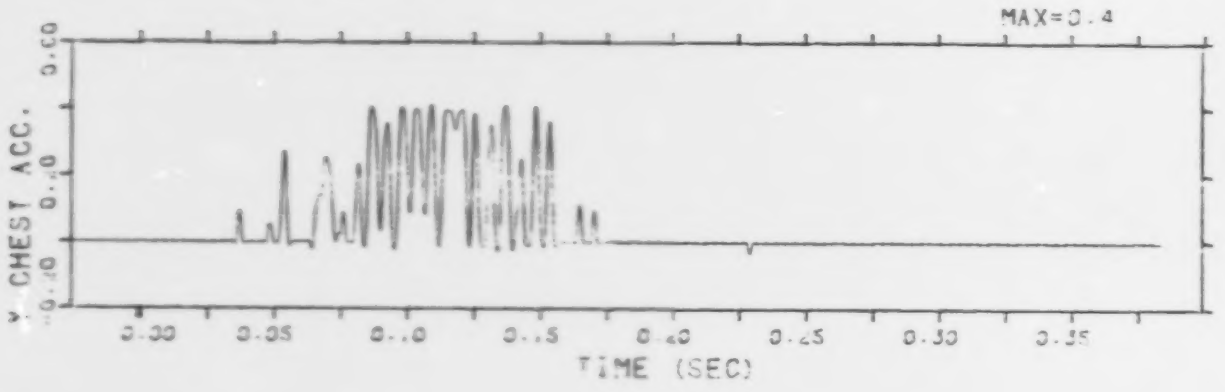

MIN=-4.6
FIL WEB ACC LO-G
3.00
-3.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

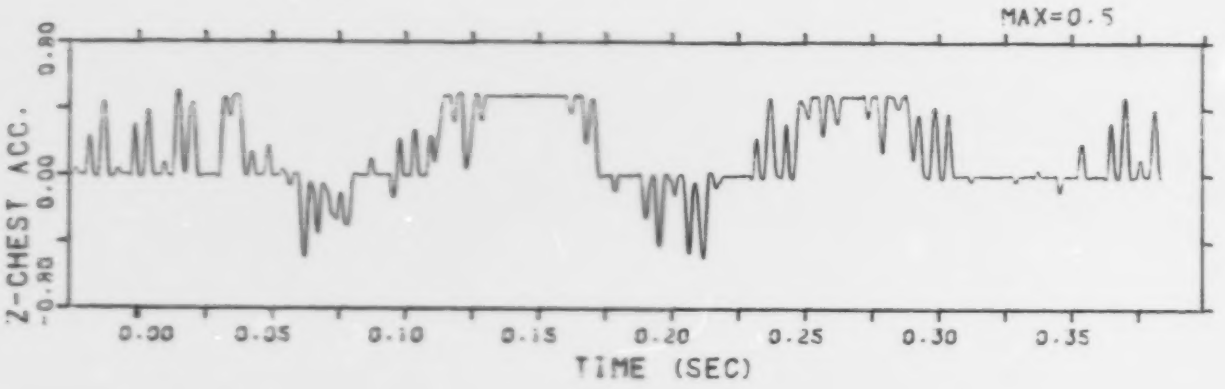

MIN=-5.0
FIL WEB ACC HI-G
3.00
-3.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

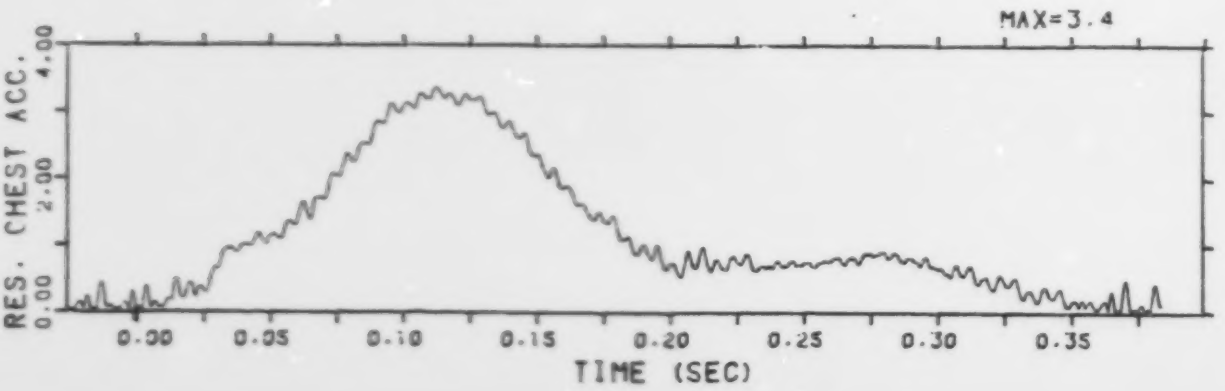

MIN=-5.5
FIL HRD ACC LO-G
8.00
-8.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-5.9
FIL HRD ACC HI-G
8.00
-8.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-3.4
X-CHEST ACC.
0.00
-1.40
-3.40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=0.4
Y-CHEST ACC.
0.00
0.20
-0.20
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=0.5
Z-CHEST ACC.
0.80
0.00
-0.80
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MAX=3.4
RES. CHEST ACC.
4.00
2.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

DK:DFS475.DAT

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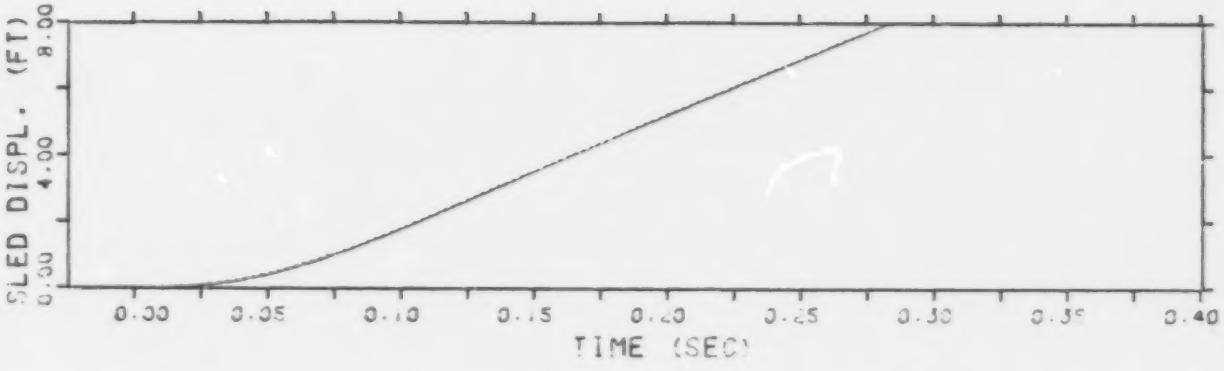
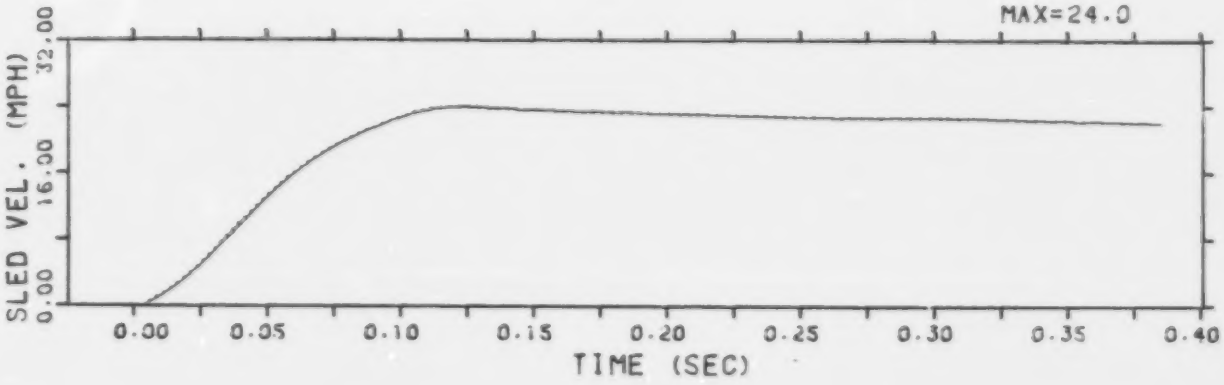
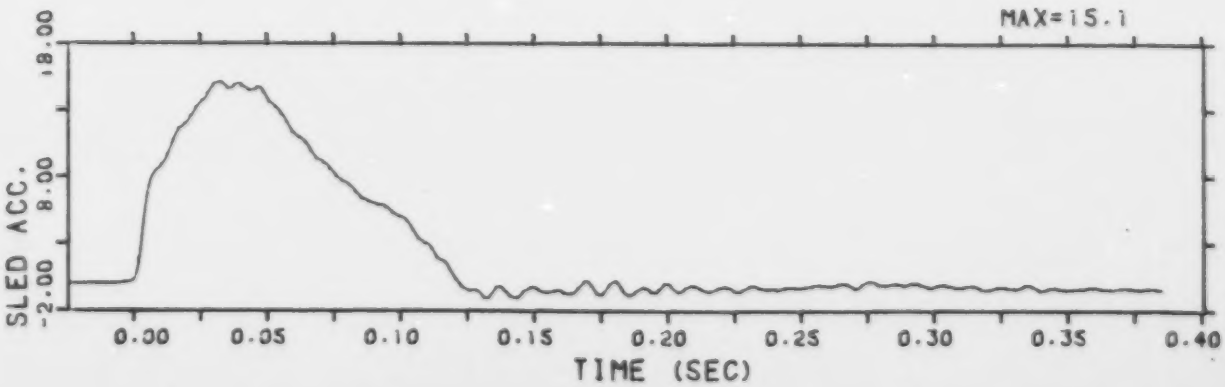
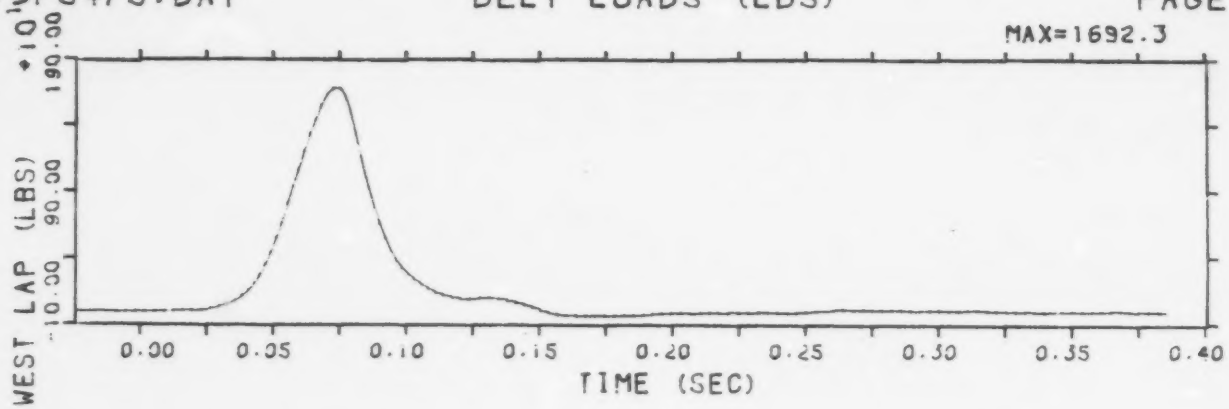
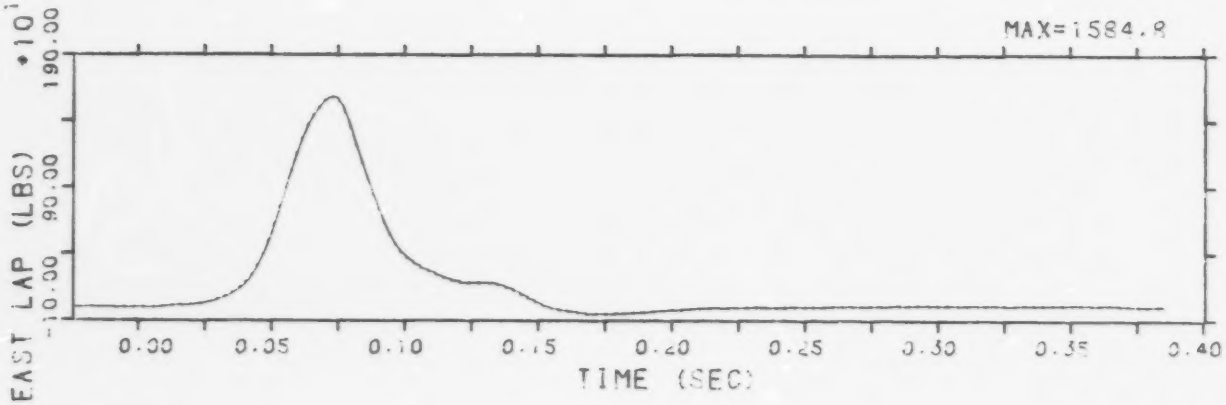
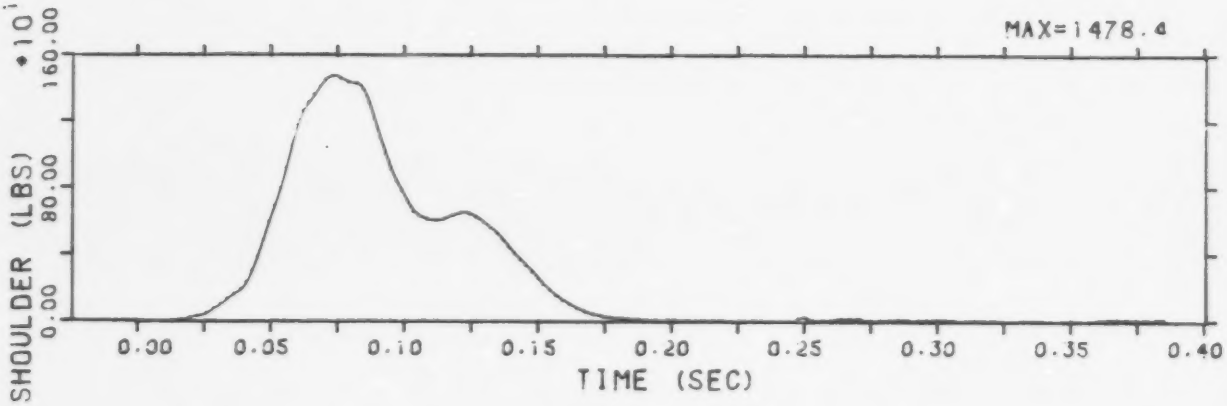


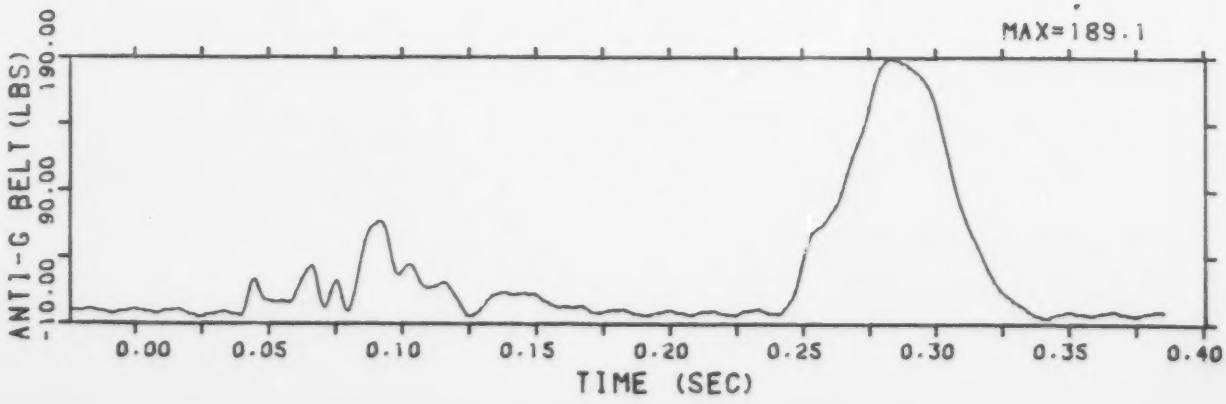


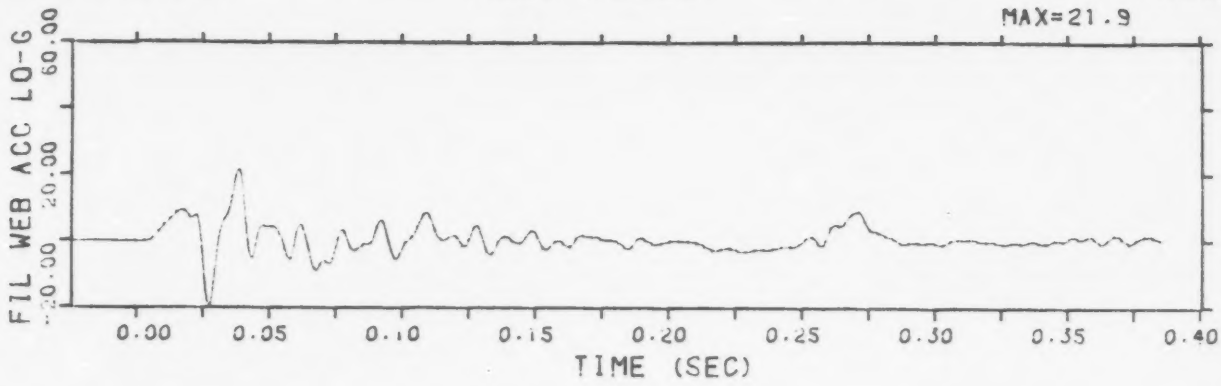


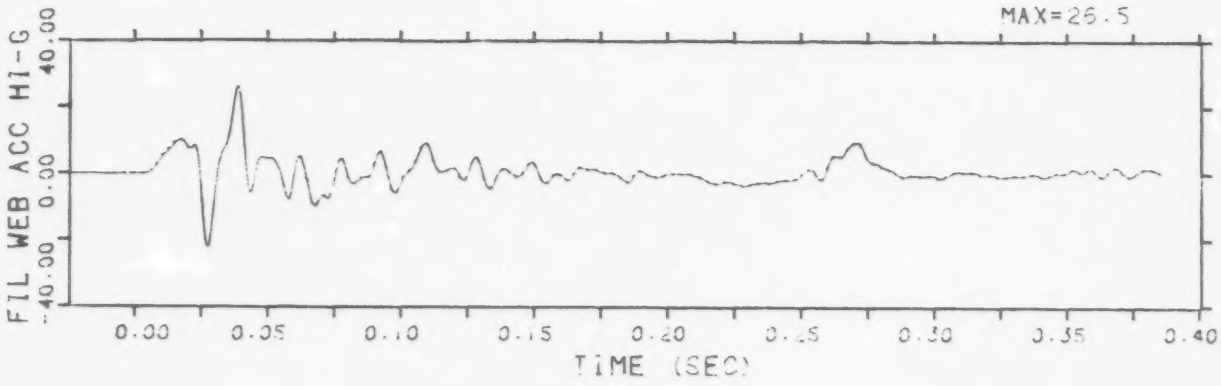

MAX=1692.3
•10¹
190.00
90.00
-10.00
WEST LAP (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

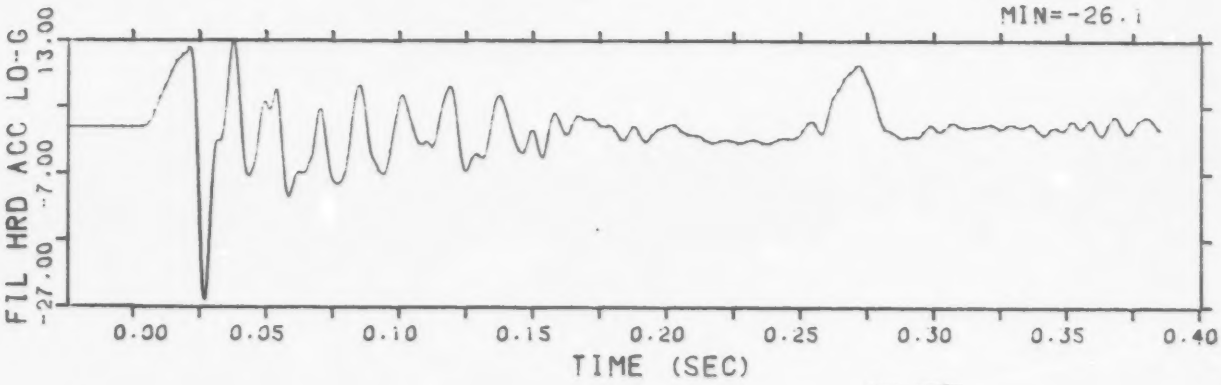

MAX=1584.8
•10¹
190.00
90.00
-10.00
EAST LAP (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

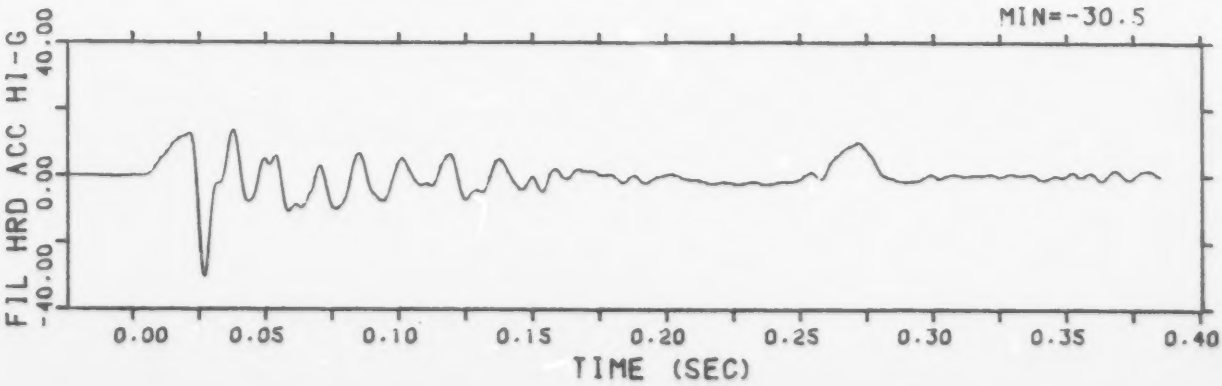

MAX=1478.4
•10¹
160.00
80.00
0.00
SHOULDER (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

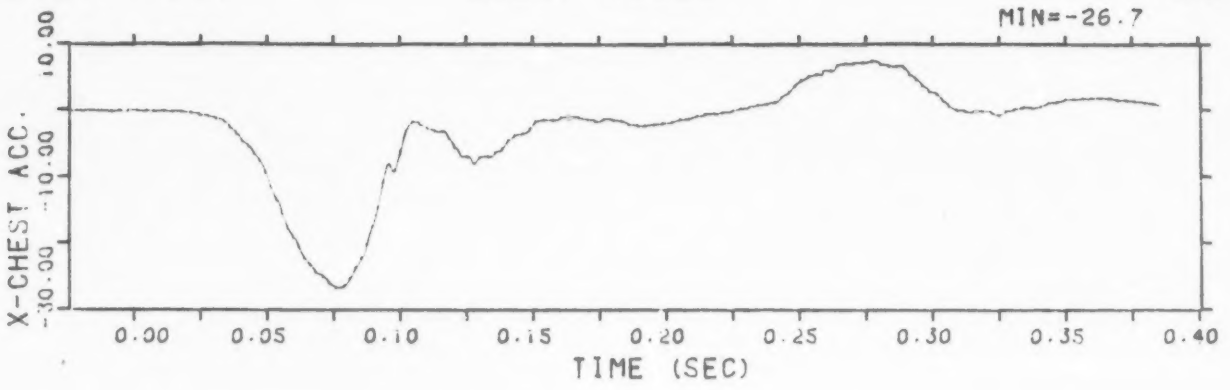

MAX=189.1
190.00
90.00
-10.00
ANTI-G BELT (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

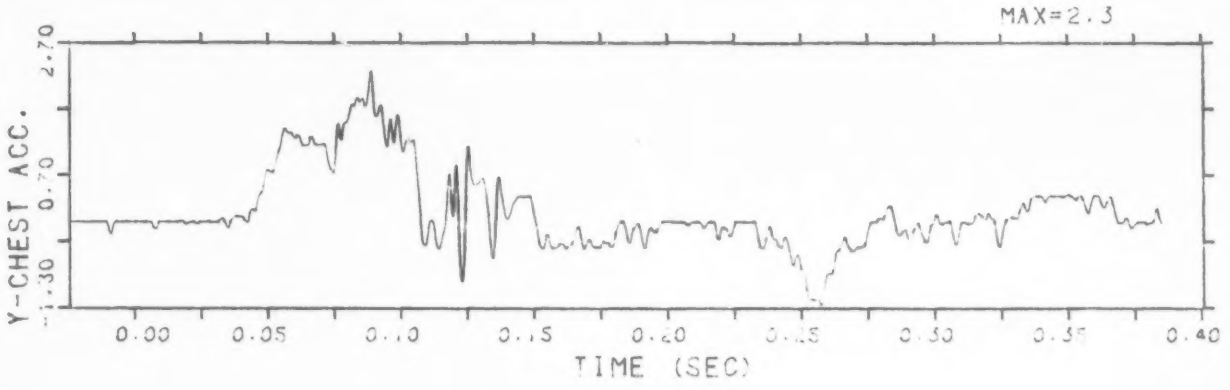

MAX=21.9
FIL WEB ACC LO-G
60.00
20.00
-20.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

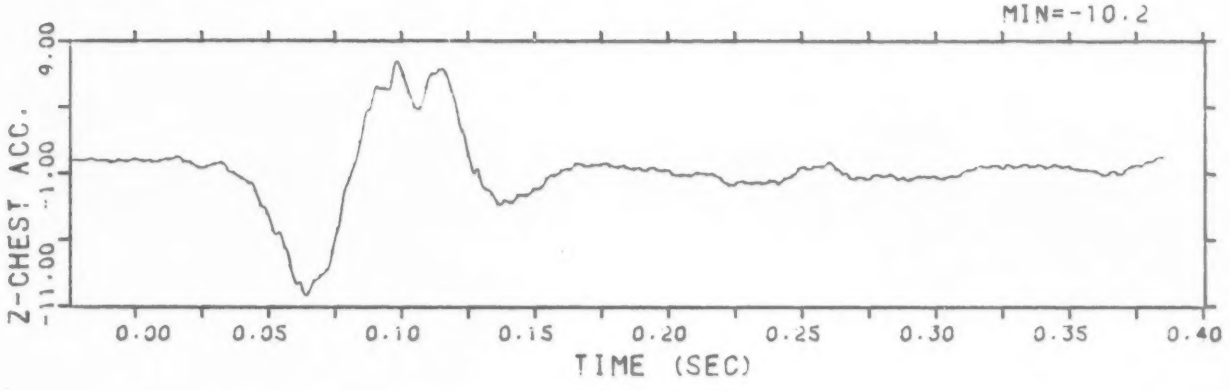

MAX=26.5
FIL WEB ACC HI-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

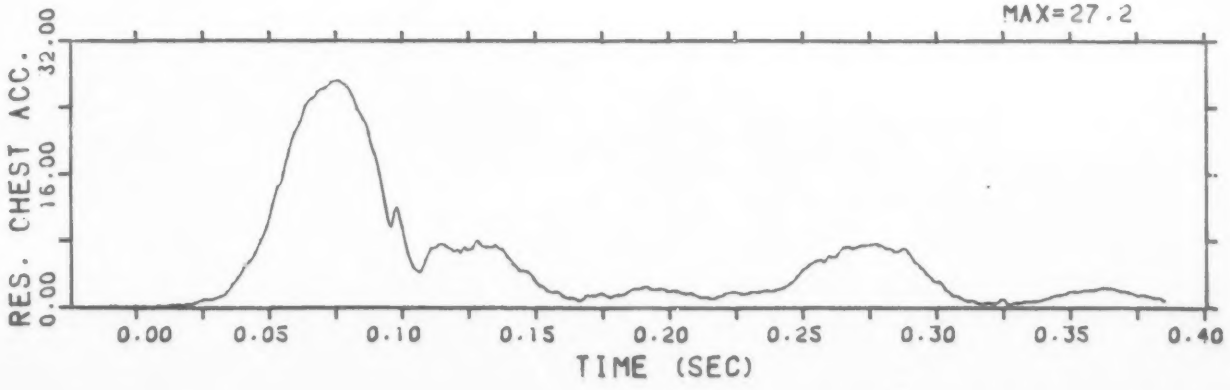

MIN=-26.1
FIL HRD ACC LO-G
13.00
-7.00
-27.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-30.5
FIL HRD ACC HI-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-26.7
X-CHEST ACC.
10.00
-10.00
-30.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=2.3
Y-CHEST ACC.
2.70
0.70
-1.30
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-10.2
Z-CHEST ACC.
9.00
-1.00
-11.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=27.2
RES. CHEST ACC.
32.00
16.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

DK:DFS476.DAT

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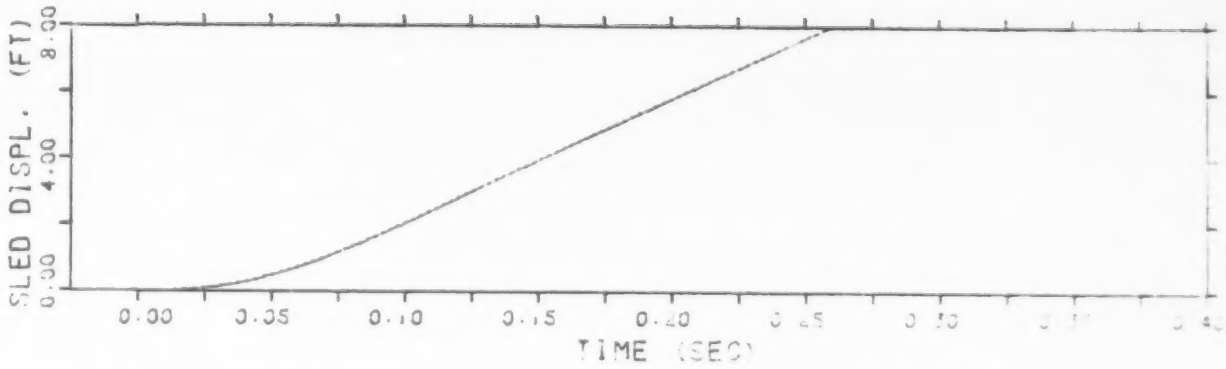
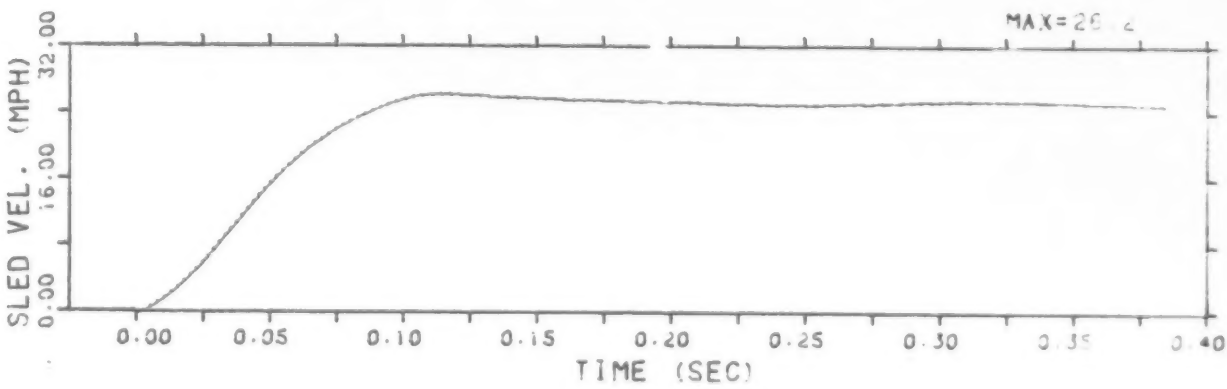
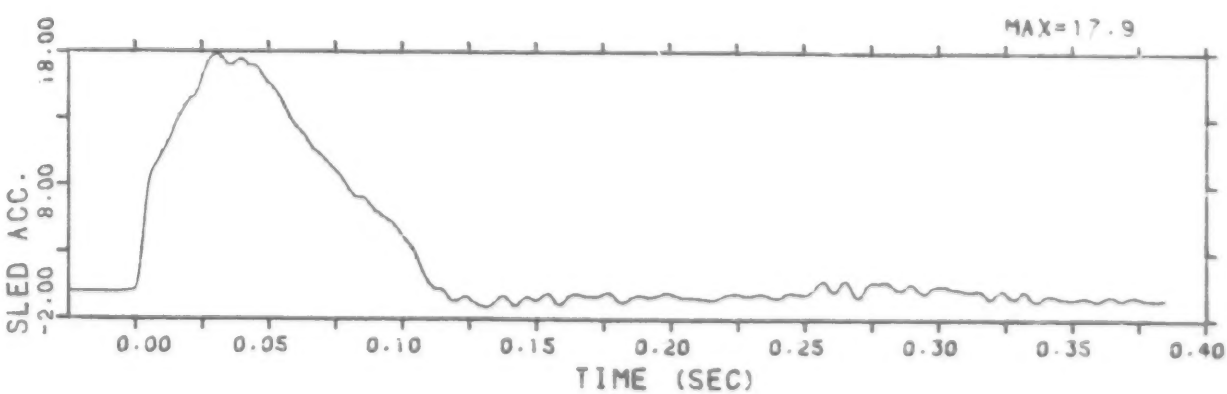
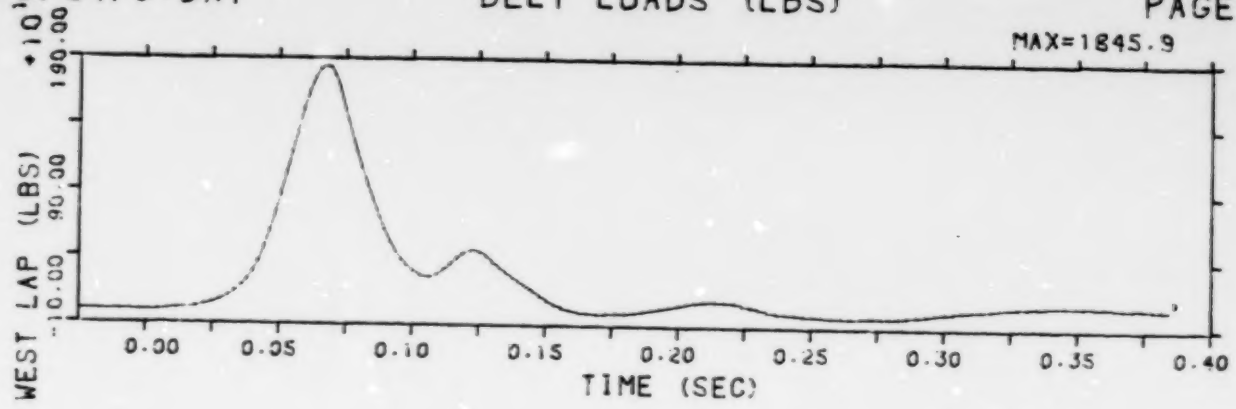
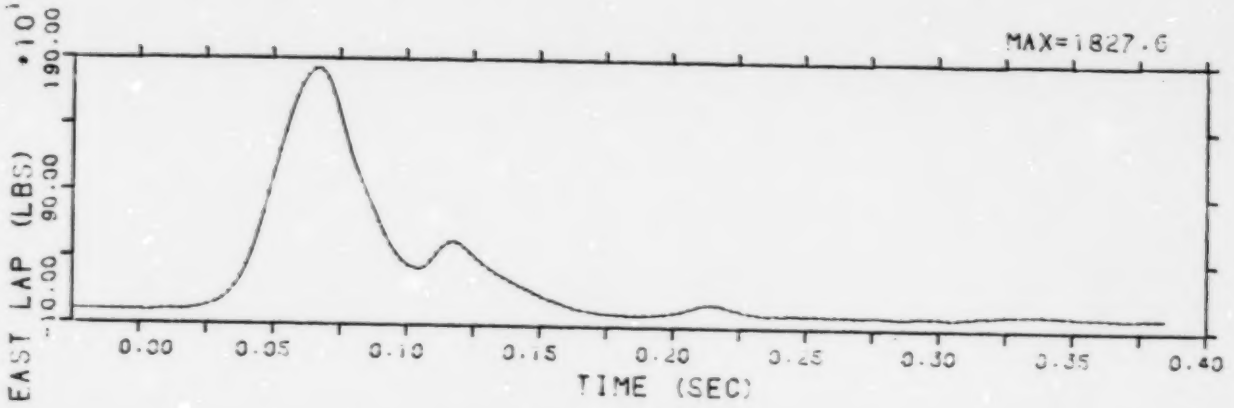
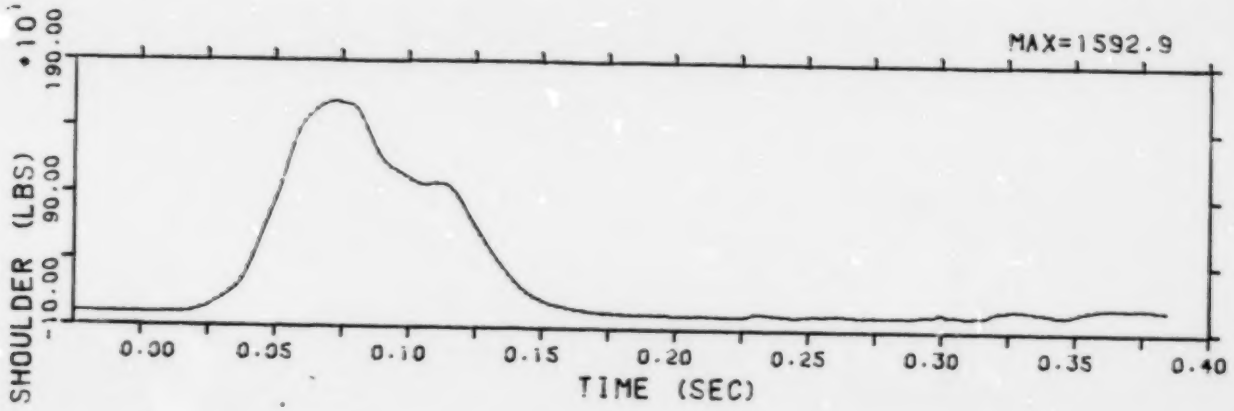


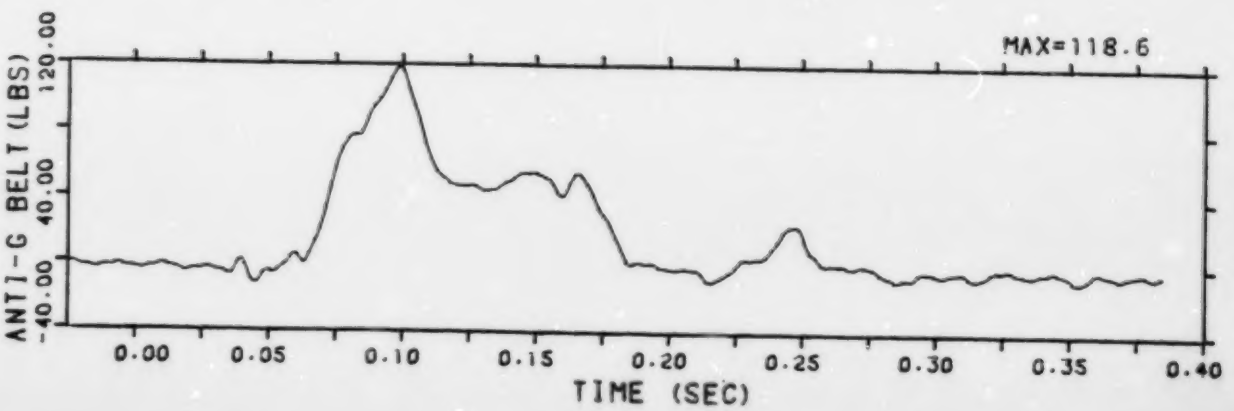


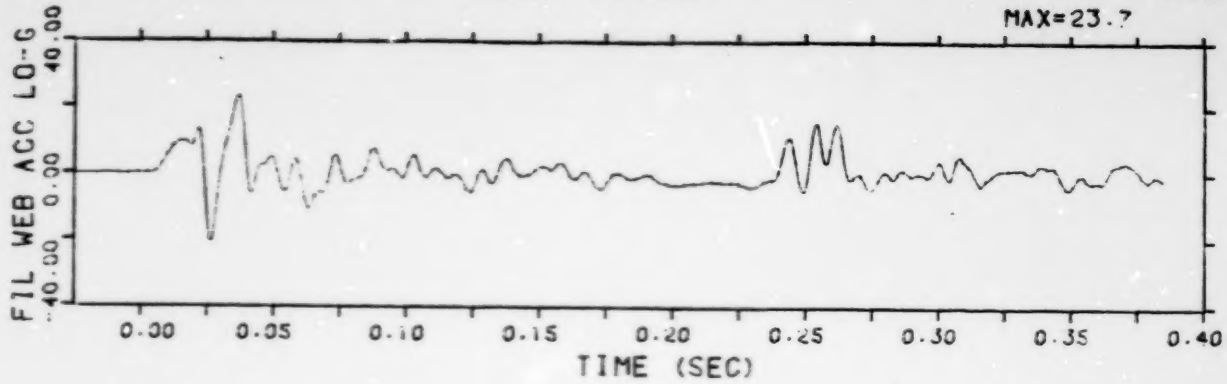


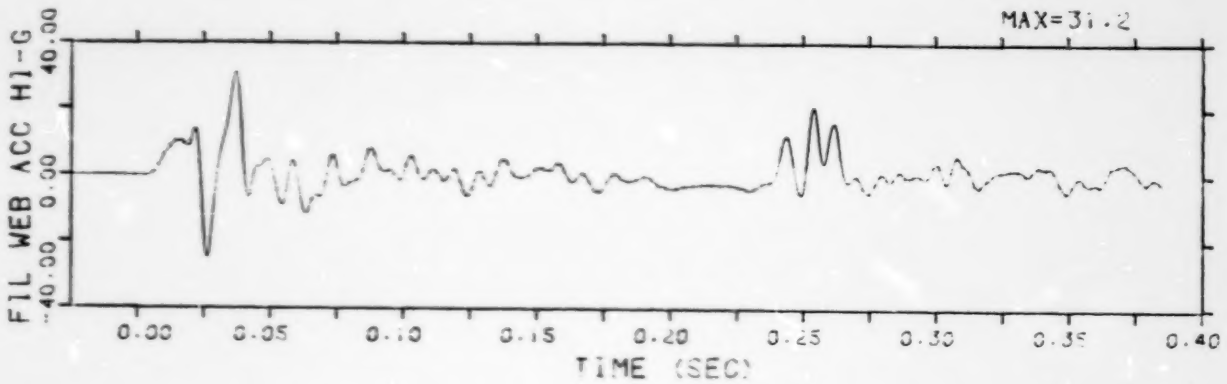

MAX=1845.9
•10¹
190.00
90.00
-10.00
WEST LAP (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

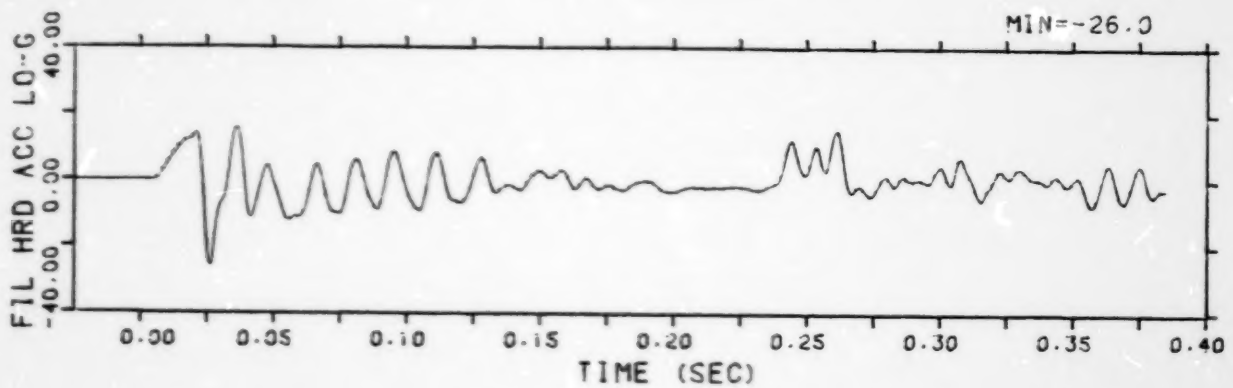

MAX=1827.6
•10¹
190.00
90.00
-10.00
EAST LAP (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

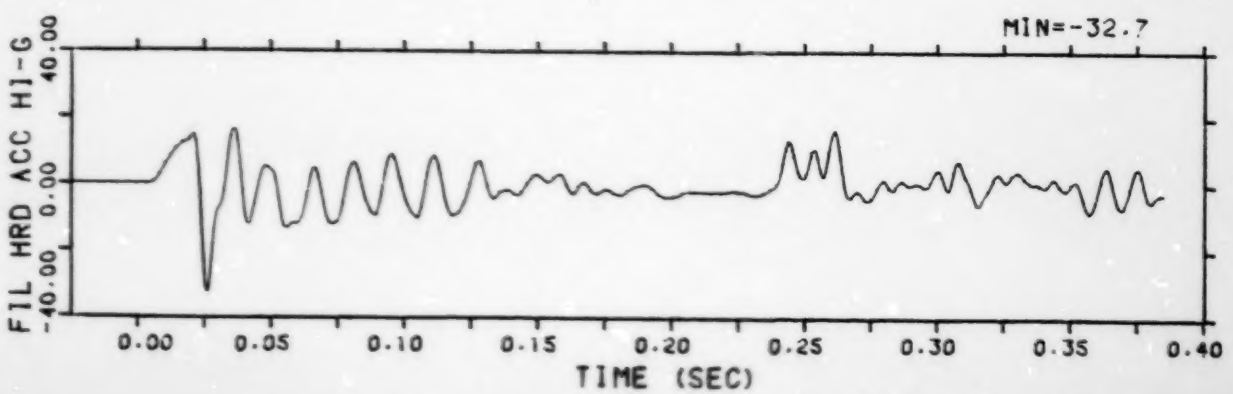

MAX=1592.9
•10¹
190.00
90.00
-10.00
SHOULDER (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

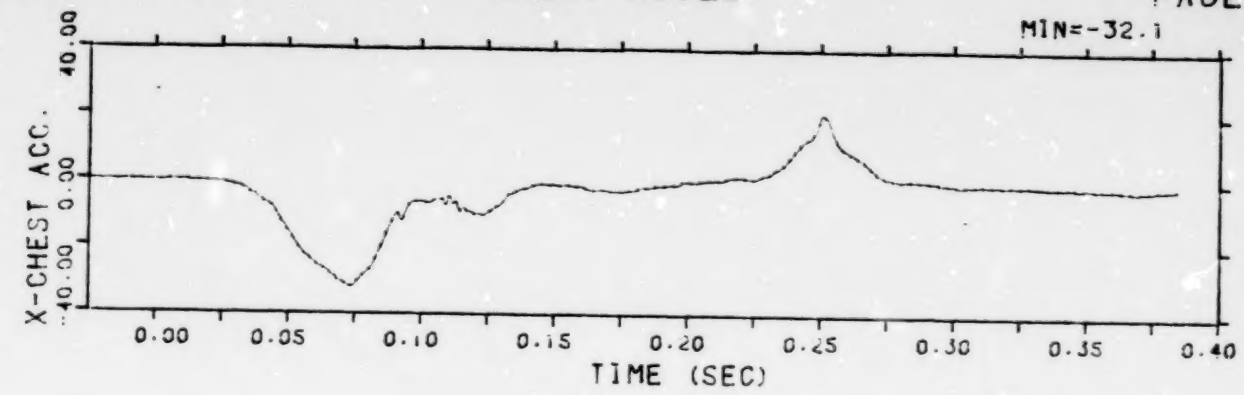

MAX=118.6
120.00
40.00
-40.00
ANTI-G BELT (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

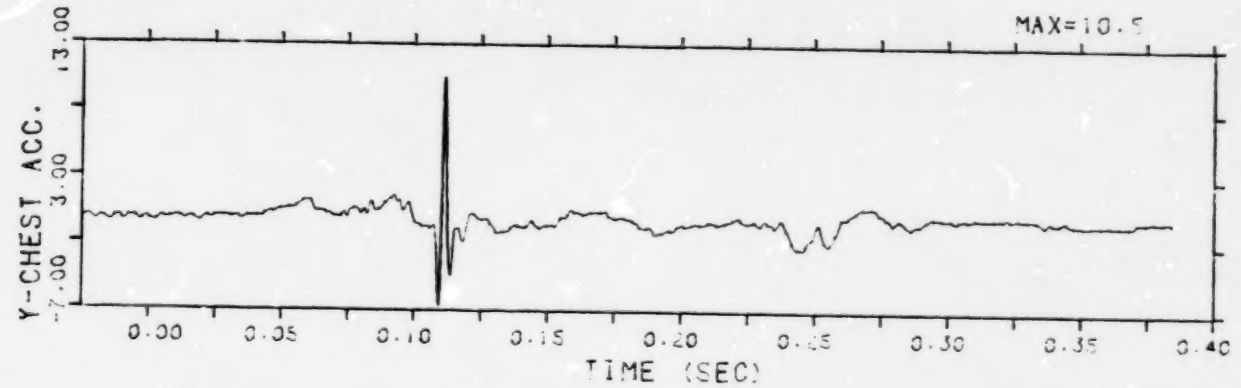

MAX=23.7
FIL WEB ACC LO-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

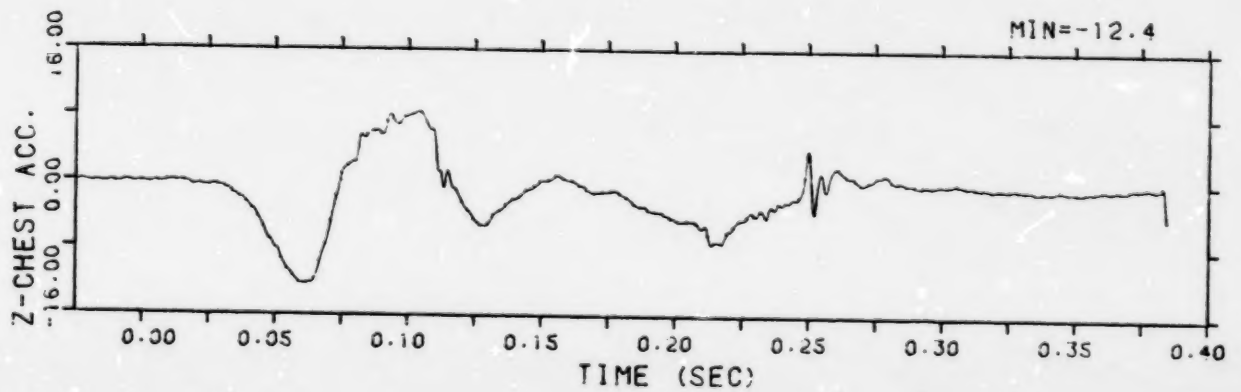

MAX=31.2
FIL WEB ACC HI-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

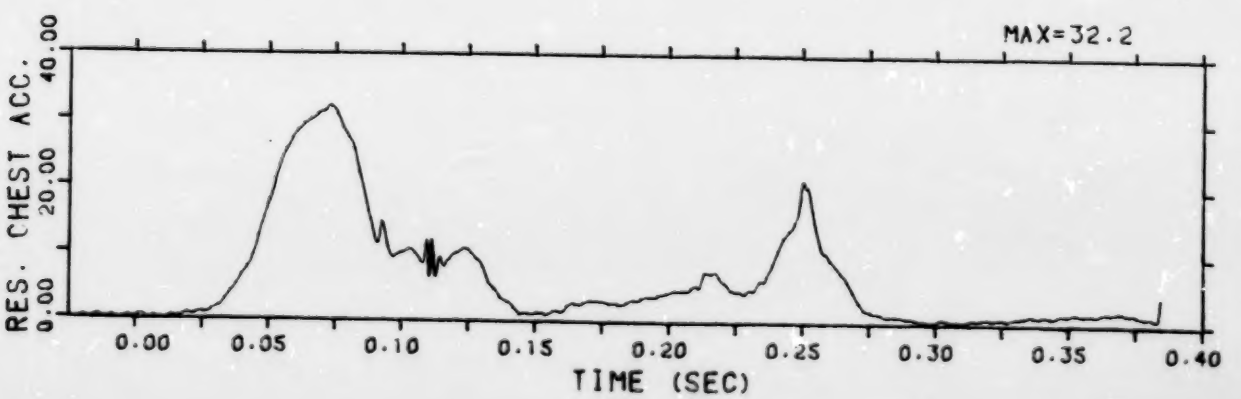

MIN=-26.0
FIL HRD ACC LO-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-32.7
FIL HRD ACC HI-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-32.1
X-CHEST ACC.
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=10.5
Y-CHEST ACC.
13.00
3.00
-7.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-12.4
Z-CHEST ACC.
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=32.2
RES. CHEST ACC.
40.00
20.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

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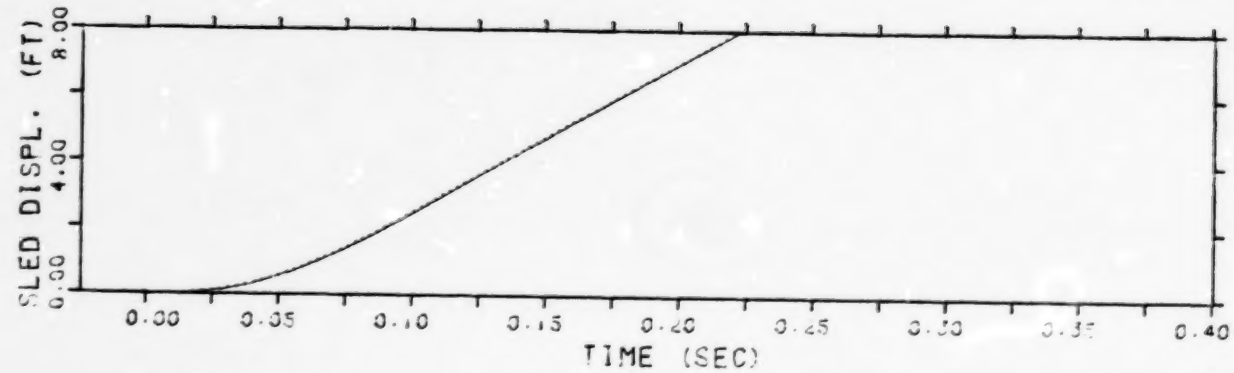
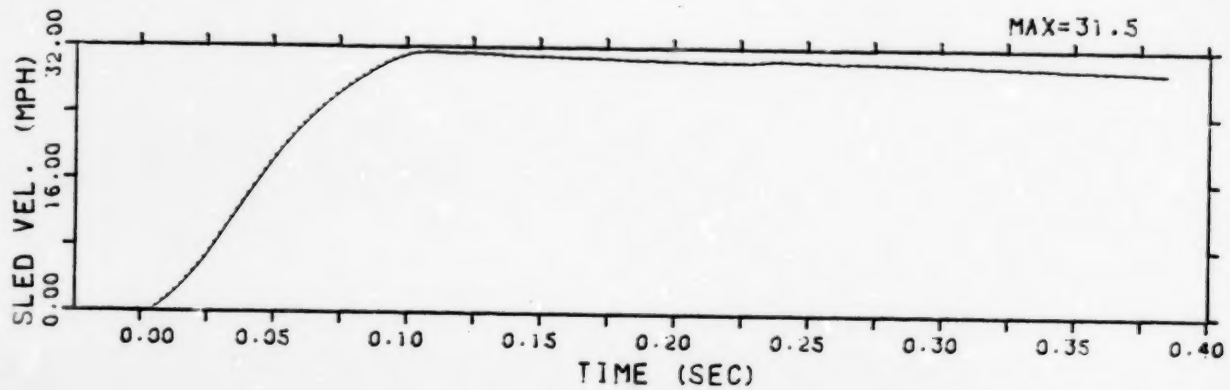
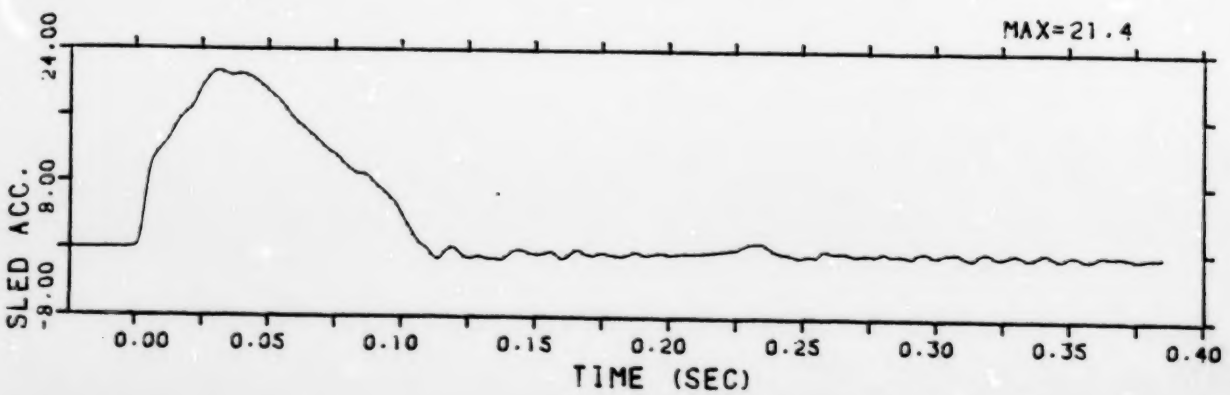
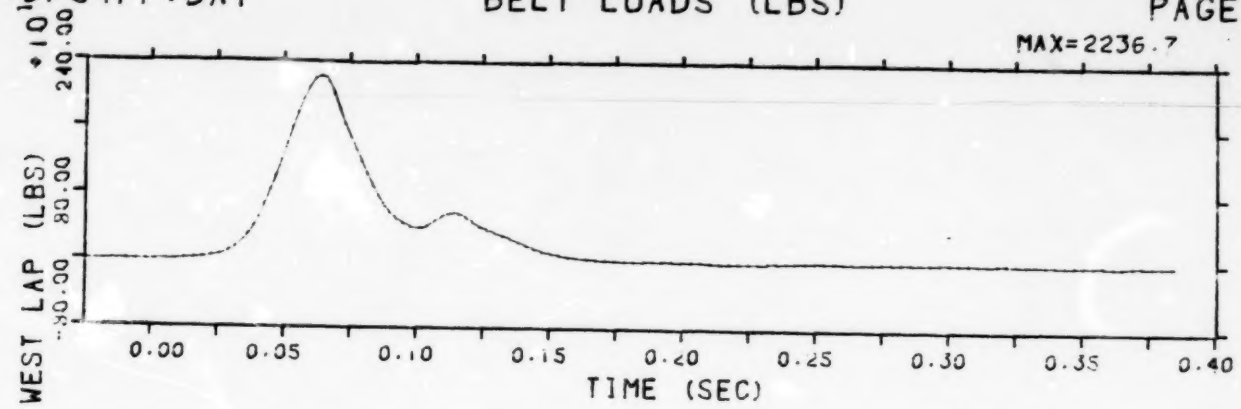
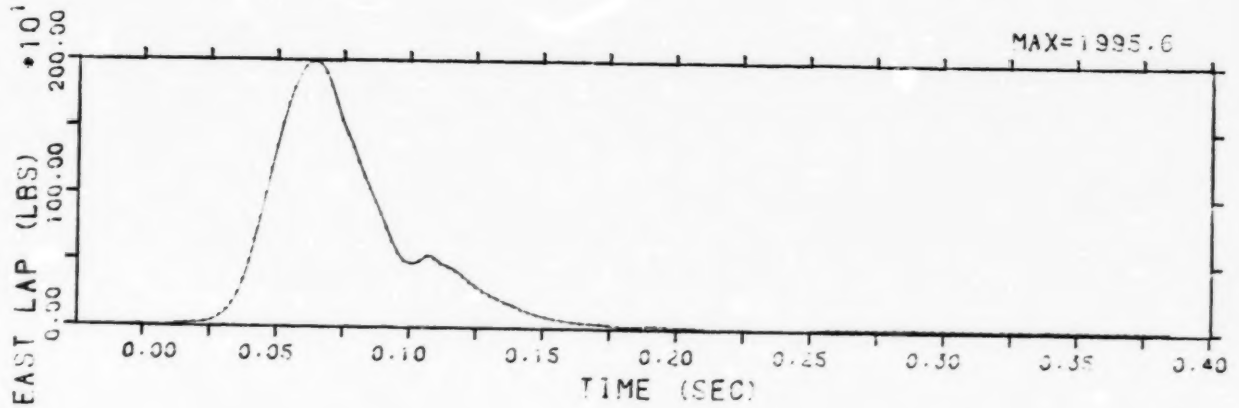
08:54:22

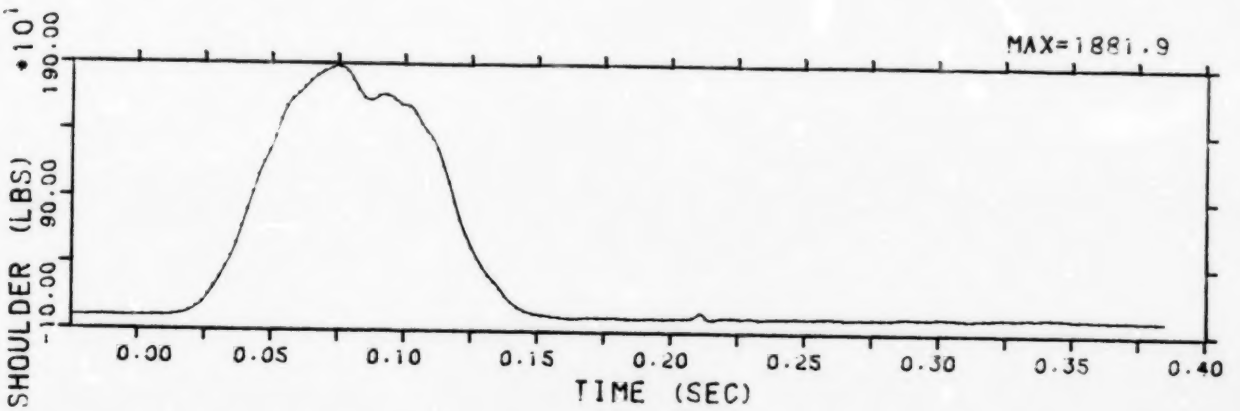


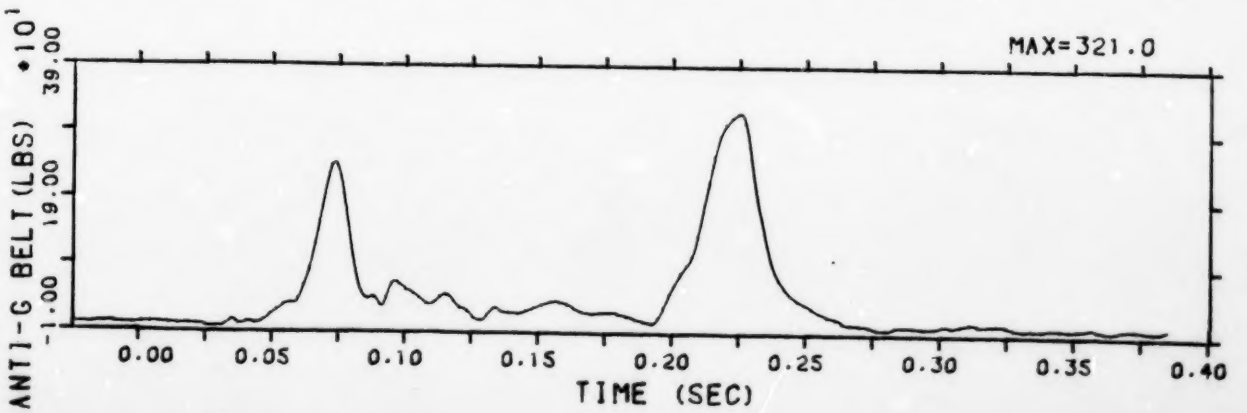


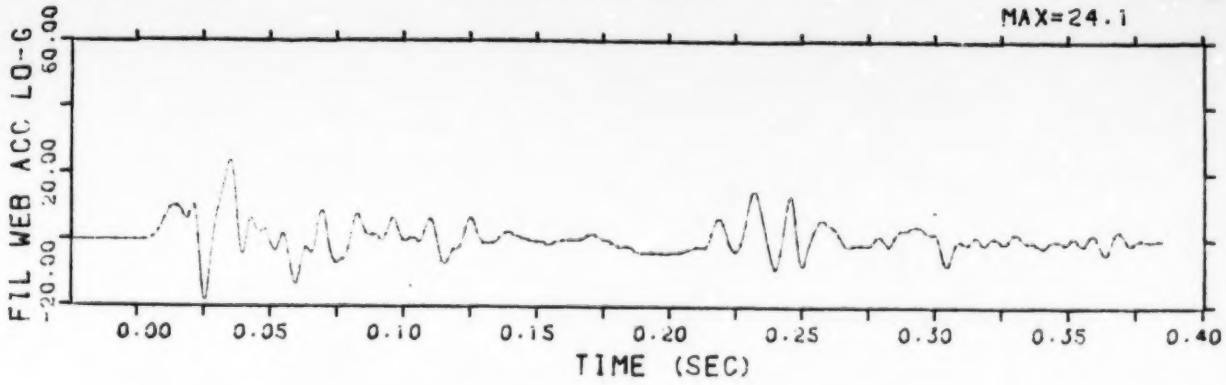


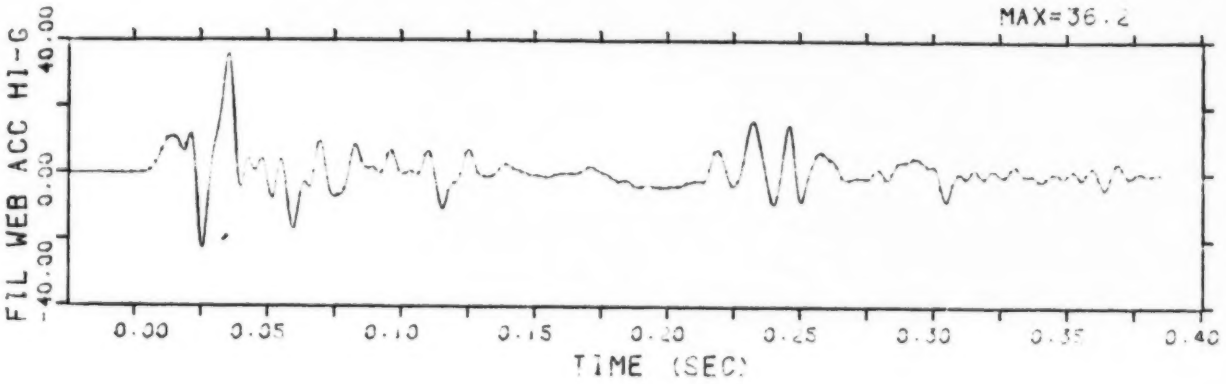

MAX=2236.7
•10¹
240.00
80.00
-80.00
WEST LAP (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

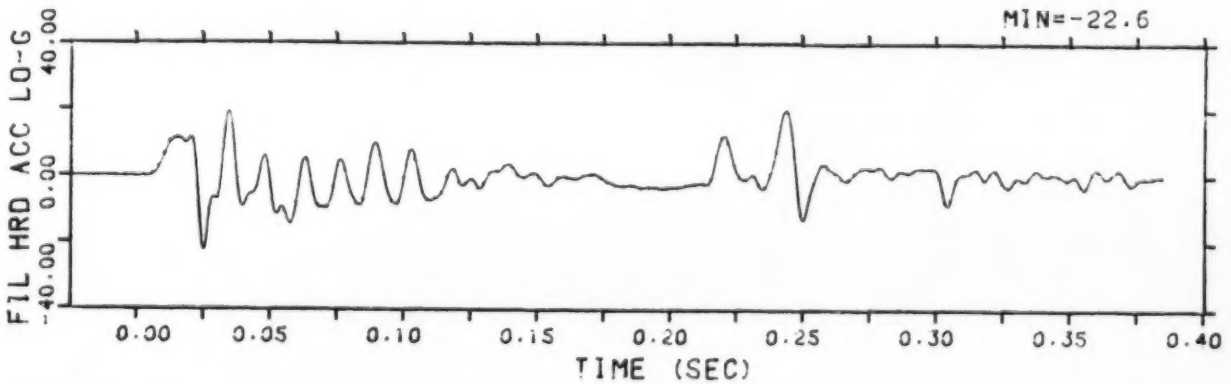

MAX=1995.6
•10¹
200.00
100.00
0.00
FAST LAP (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

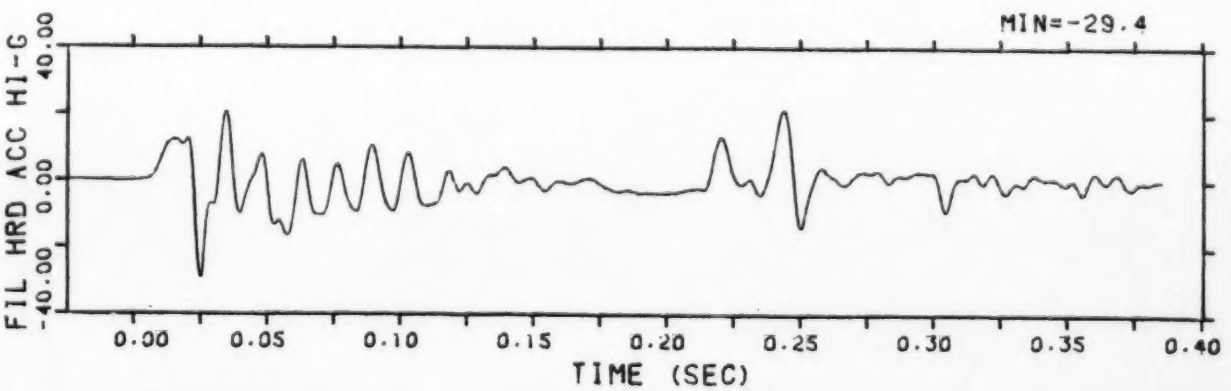

MAX=1881.9
•10¹
190.00
90.00
-10.00
SHOULDER (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

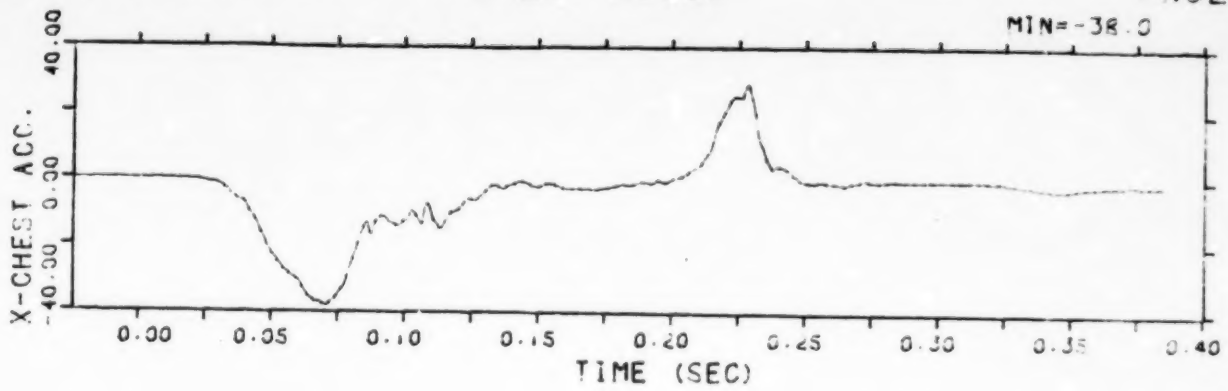

MAX=321.0
•10¹
39.00
19.00
-1.00
ANTI-G BELT (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

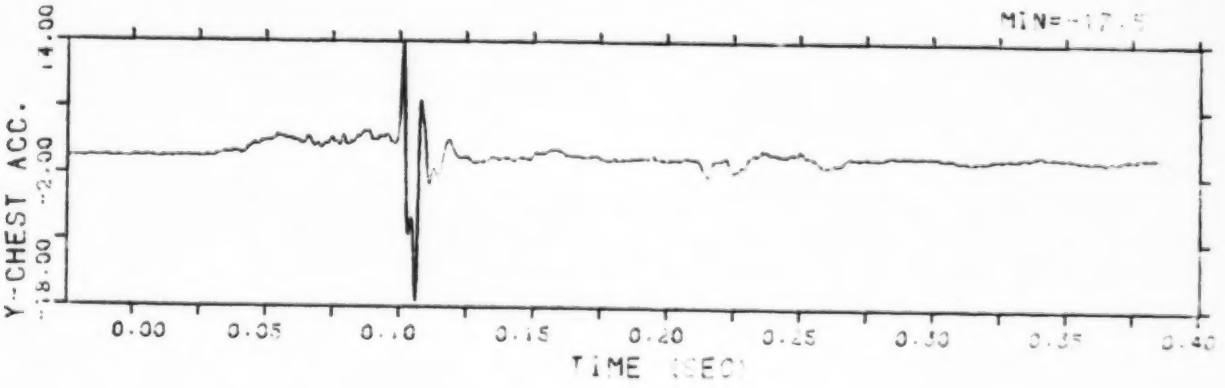

MAX=24.1
FIL WEB ACC LO-G
60.00
20.00
-20.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

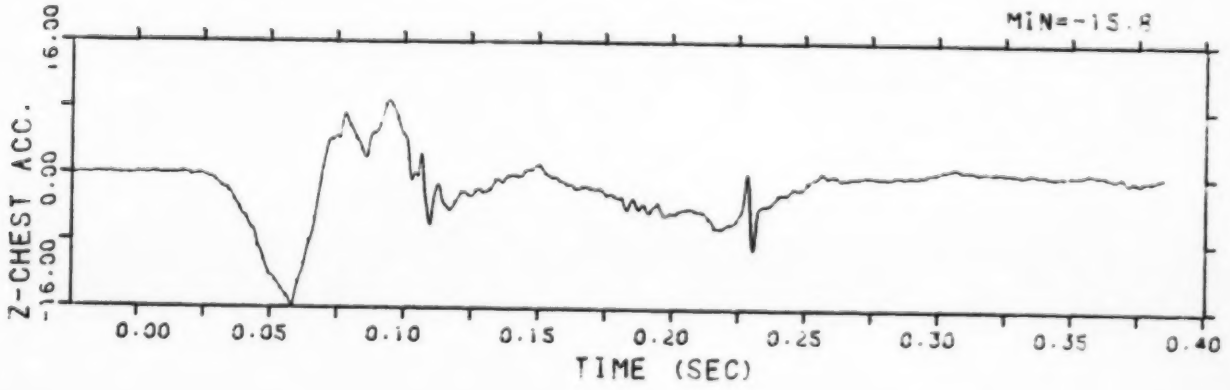

MAX=36.2
FIL WEB ACC HI-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

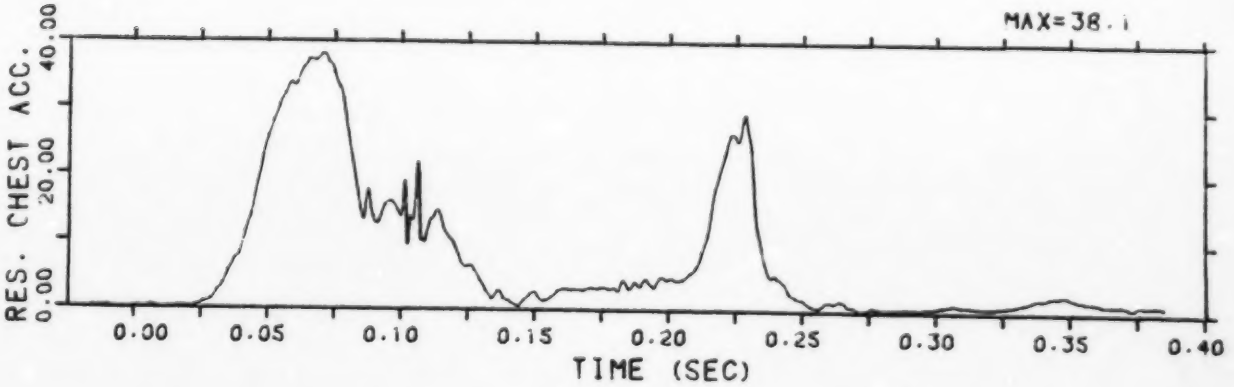

MIN=-22.6
FIL HRD ACC LO-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-29.4
FIL HRD ACC HI-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-38.0
X-CHEST ACC.
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-17.5
Y-CHEST ACC.
14.00
-2.00
-18.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-15.8
Z-CHEST ACC.
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=38.1
RES. CHEST ACC.
40.00
20.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

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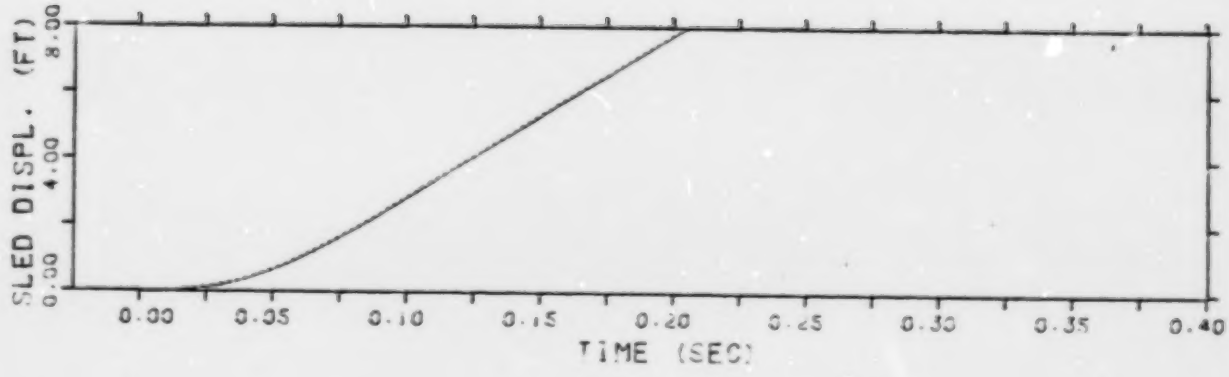
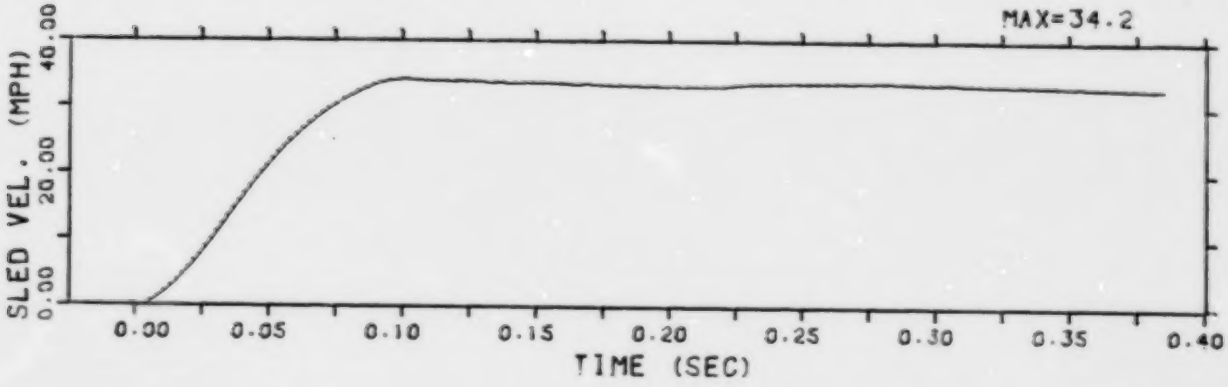
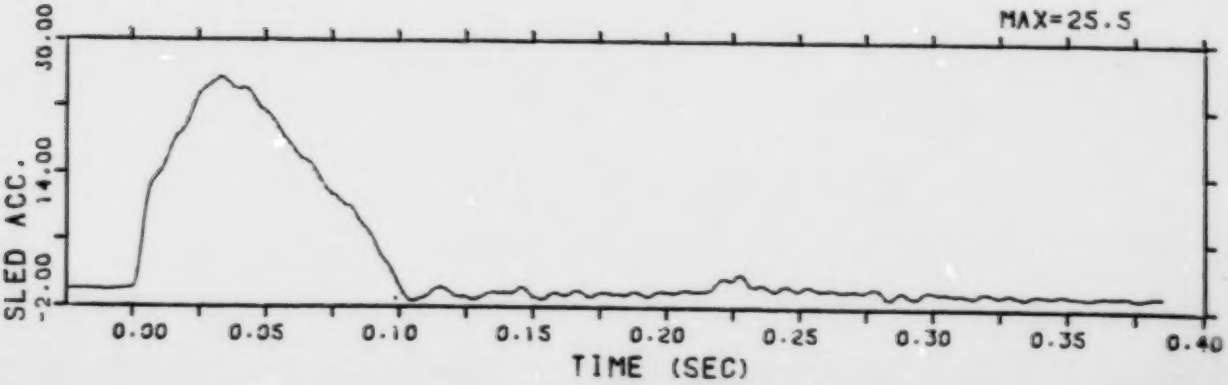
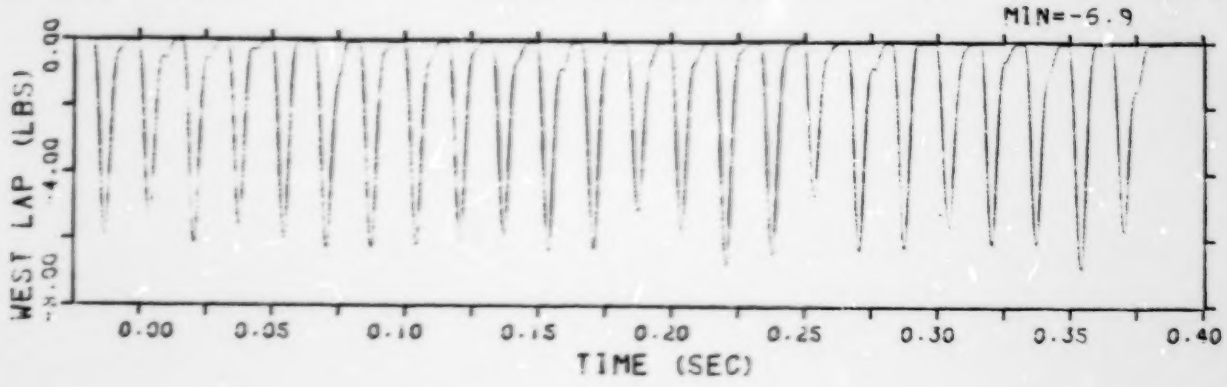
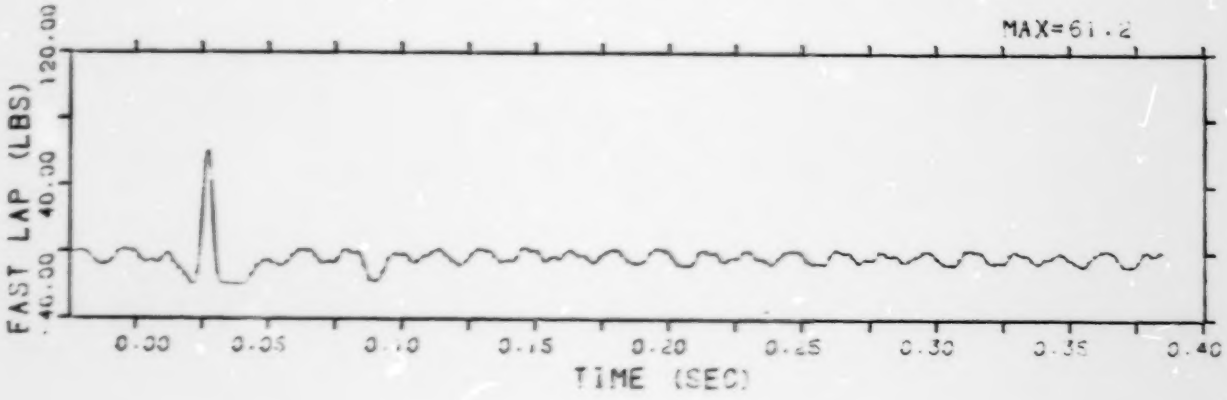
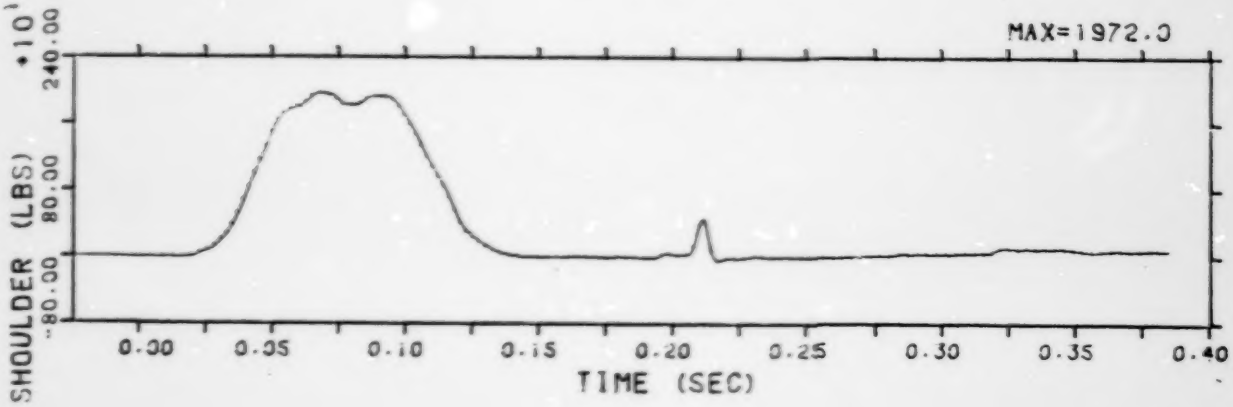


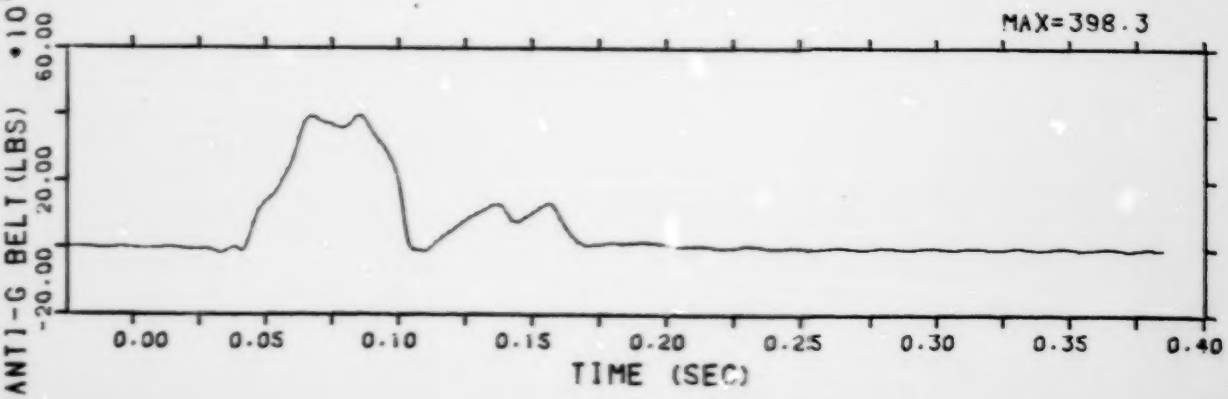


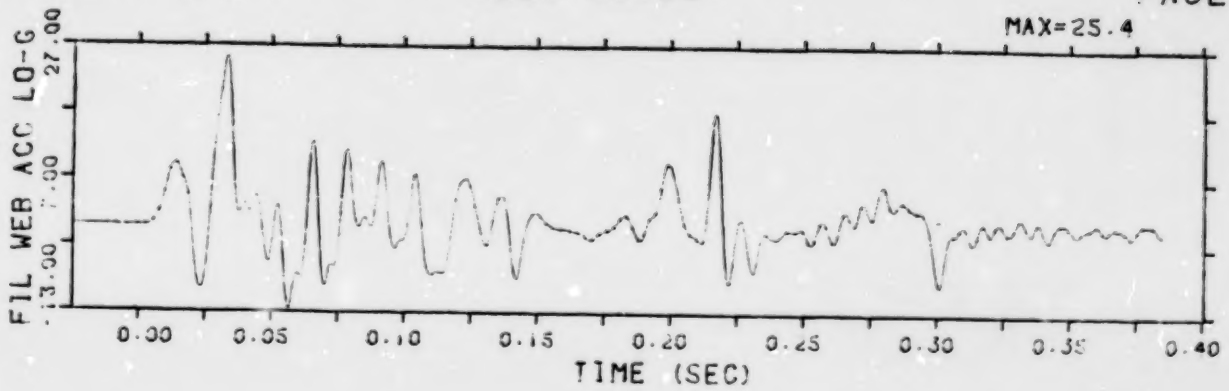


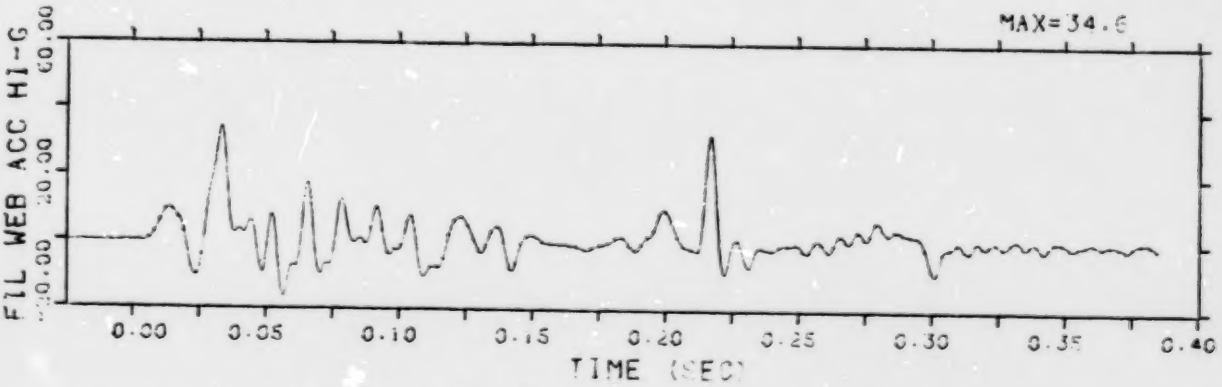

MIN=-5.9
WEST LAP (LBS)
0.00
-4.00
-8.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

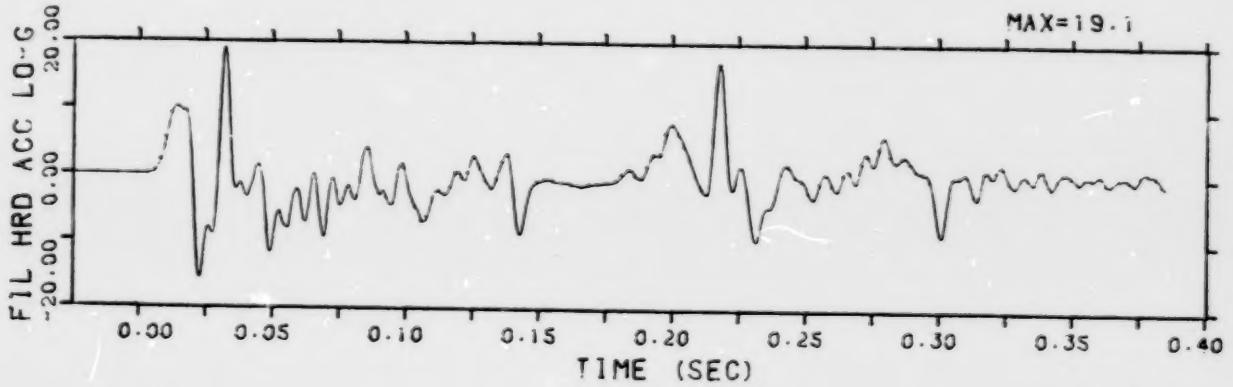

MAX=61.2
FAST LAP (LBS)
120.00
40.00
-40.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

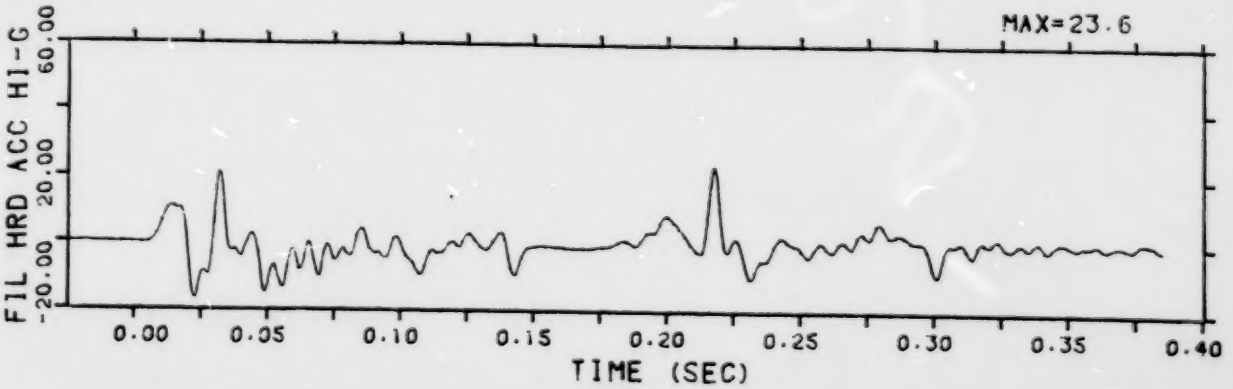

MAX=1972.0
SHOULDER (LBS) *10¹
240.00
80.00
-80.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

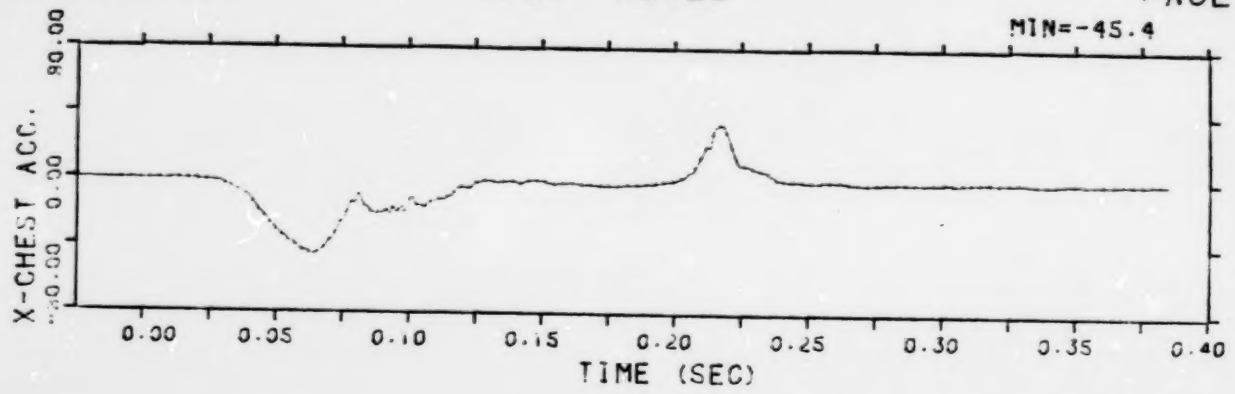

MAX=398.3
ANTI-G BELT (LBS) *10¹
60.00
20.00
-20.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

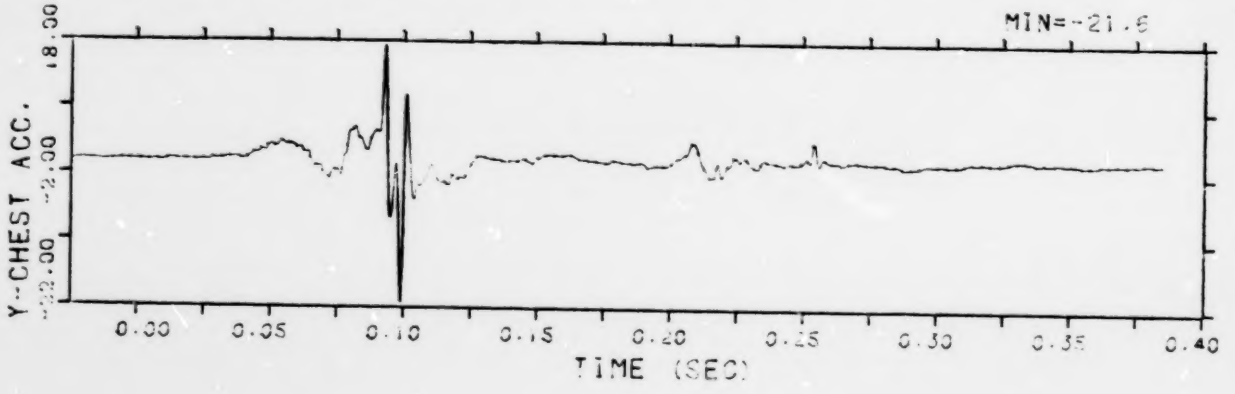

MAX=25.4
FIL WEB ACC LO-G
27.00
-13.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

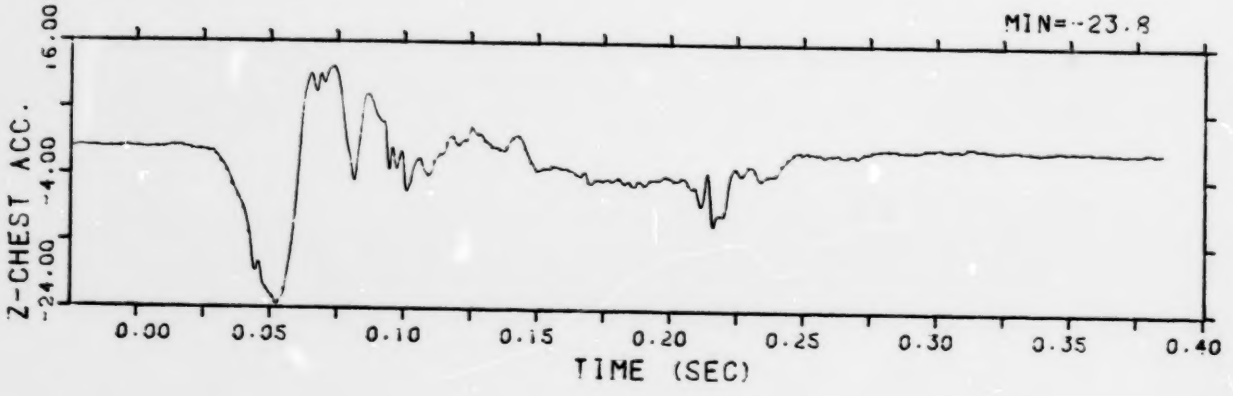

MAX=34.6
FIL WEB ACC HI-G
60.00
20.00
-20.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

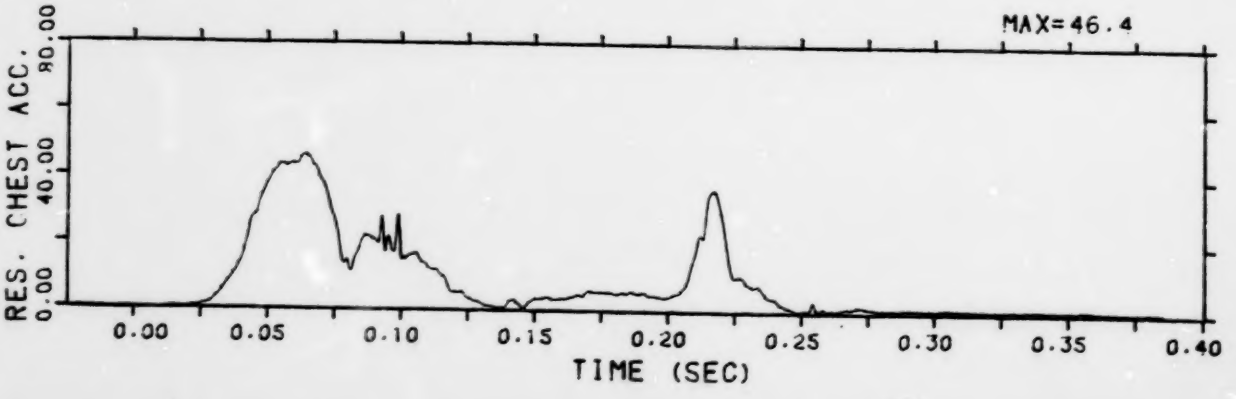

MAX=19.1
FIL HRD ACC LO-G
20.00
0.00
-20.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=23.6
FIL HRD ACC HI-G
60.00
20.00
-20.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-45.4
X-CHEST ACC.
80.00
0.00
-80.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-21.6
Y-CHEST ACC.
18.00
-2.00
-22.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-23.8
Z-CHEST ACC.
16.00
-4.00
-24.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=46.4
RES. CHEST ACC.
80.00
40.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

RK1:DFS479.DAT

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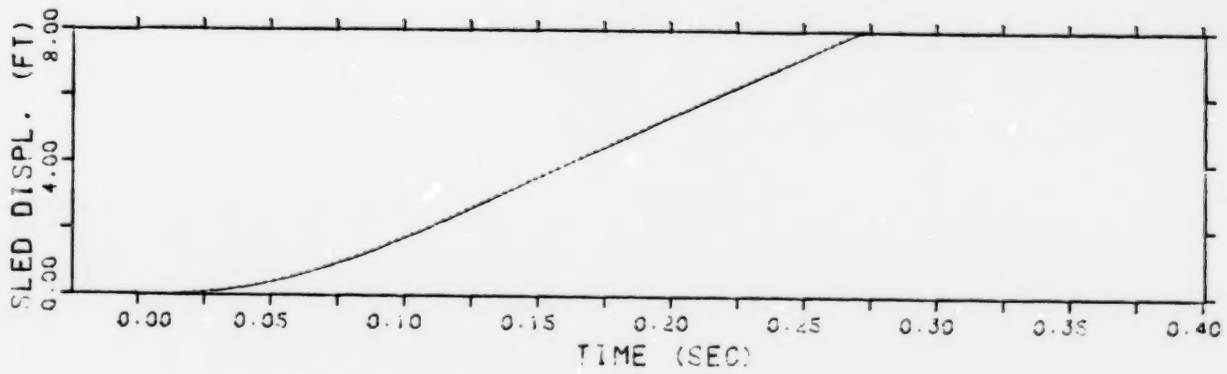
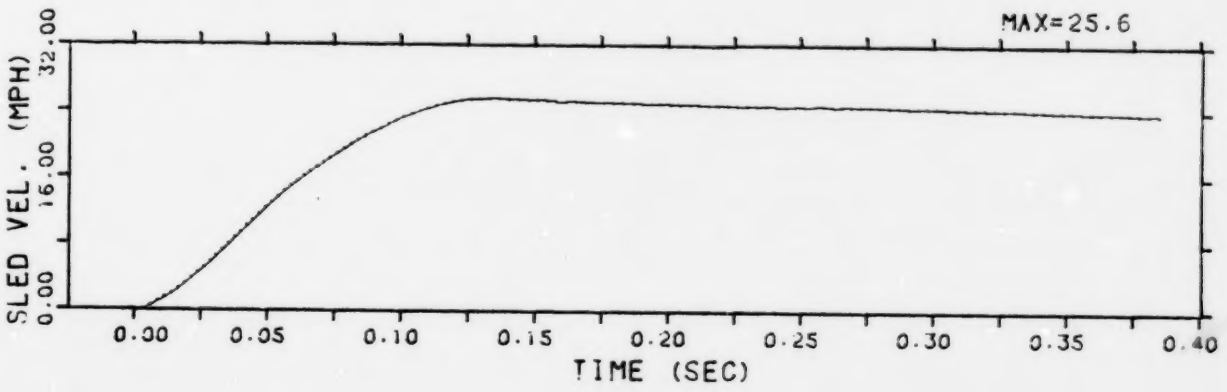
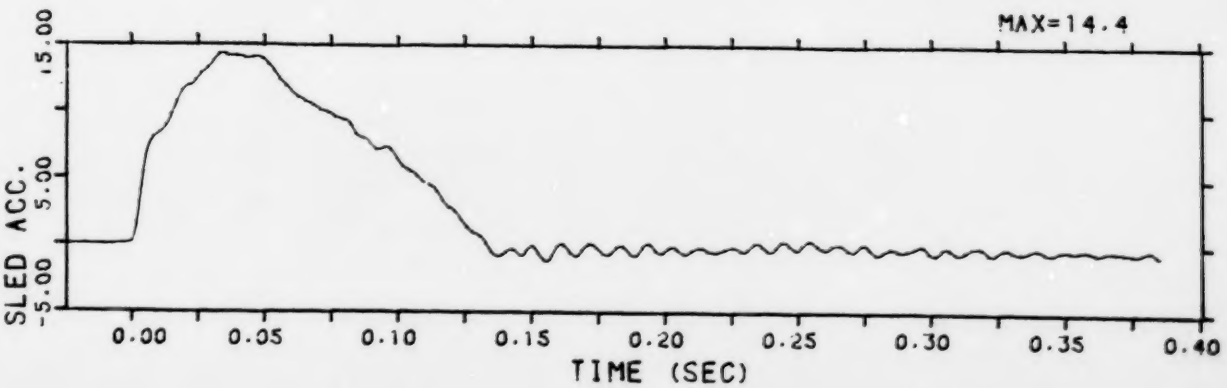
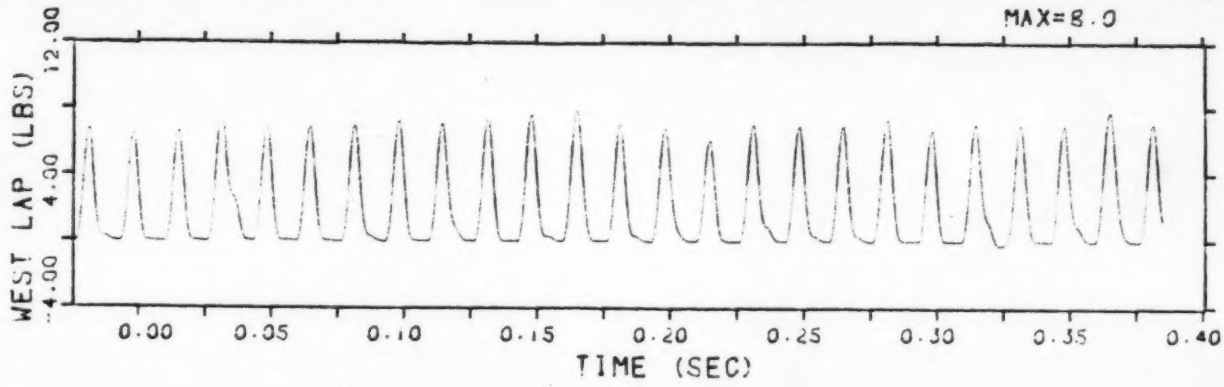
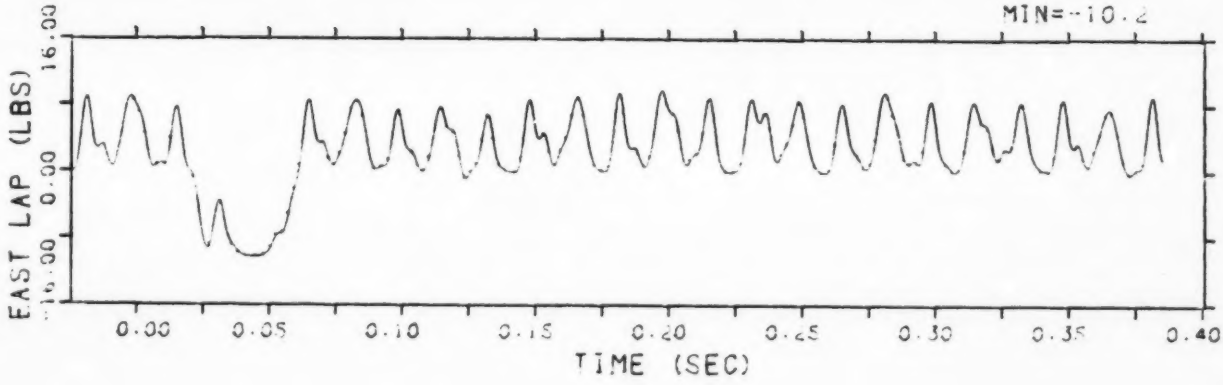
12:51:44

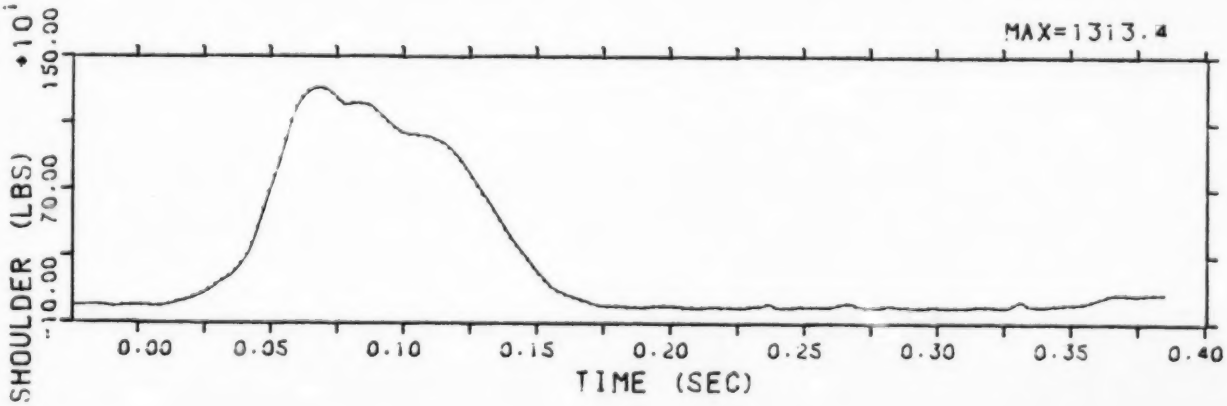


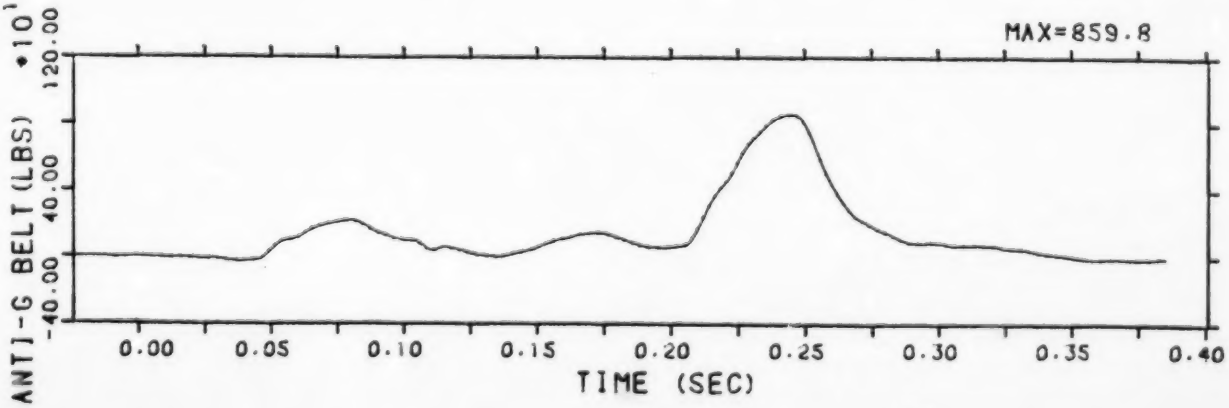


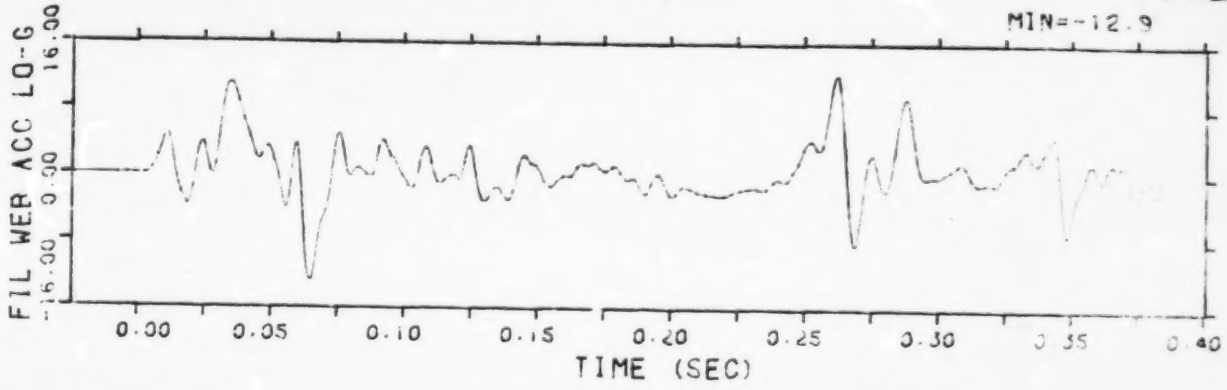


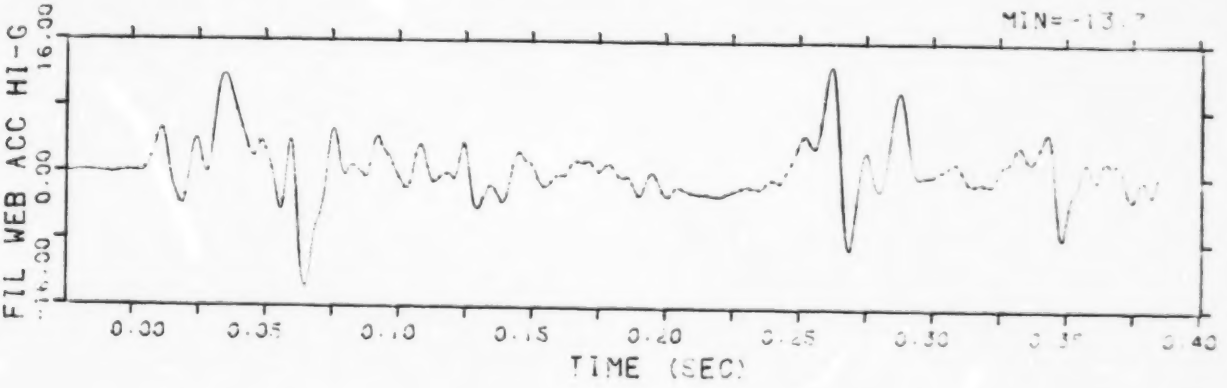

MAX=8.0
WEST LAP (LBS)
12.00
4.00
-4.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

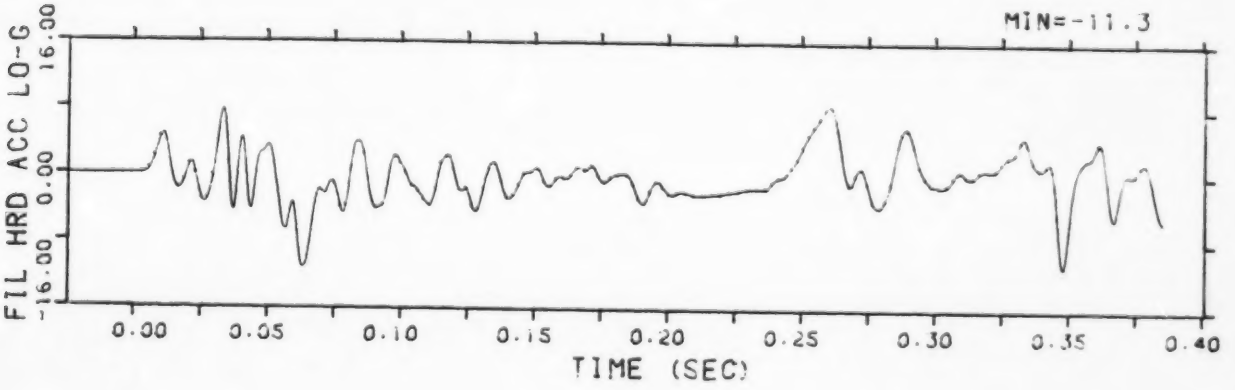

MIN=-10.2
EAST LAP (LBS)
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

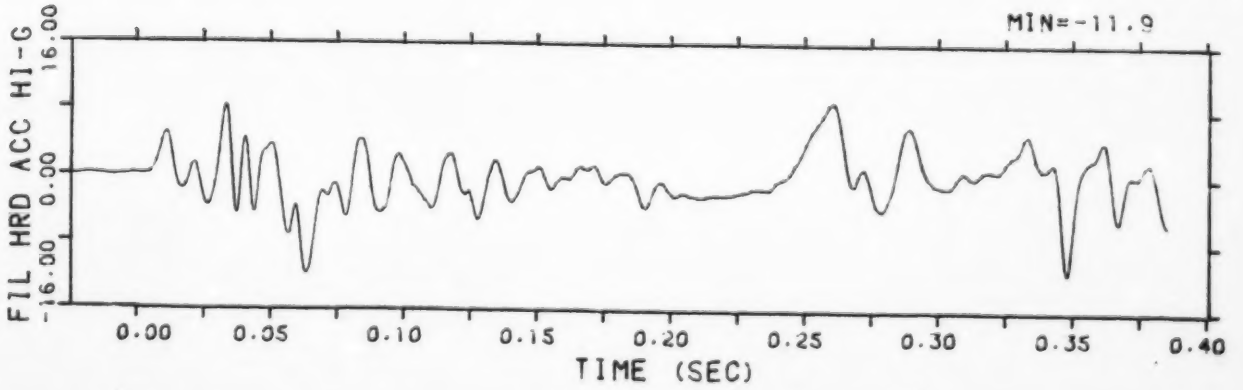

MAX=1313.4
SHOULDER (LBS) *10¹
150.00
70.00
-10.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

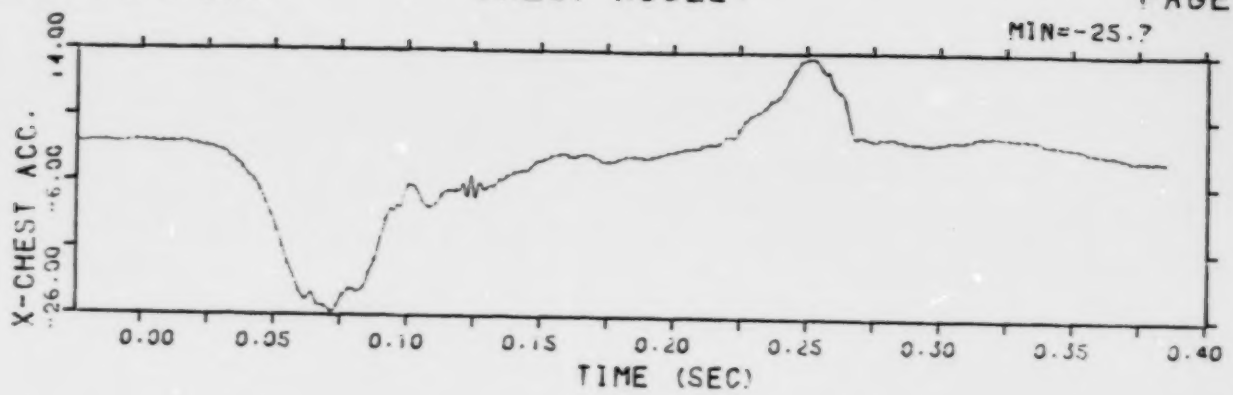

MAX=859.8
ANTI-G BELT (LBS) *10¹
120.00
40.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

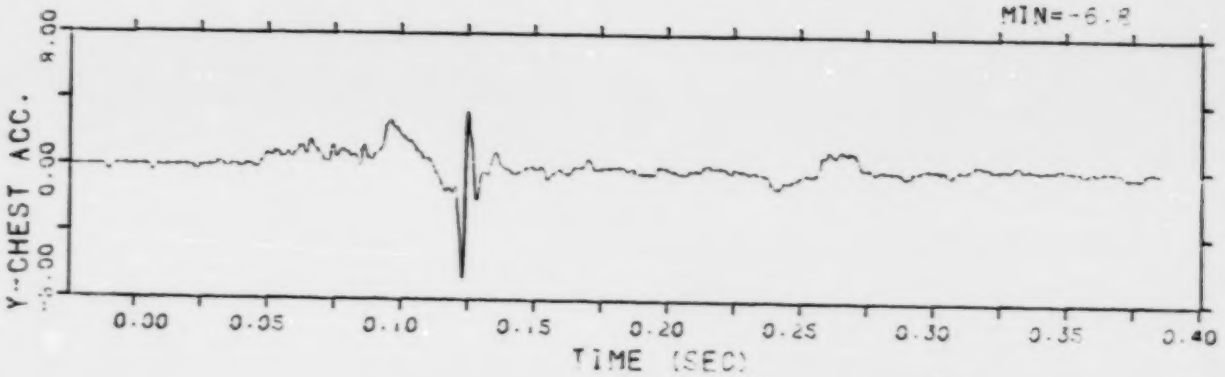

MIN=-12.9
FIL WEB ACC LO-G
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

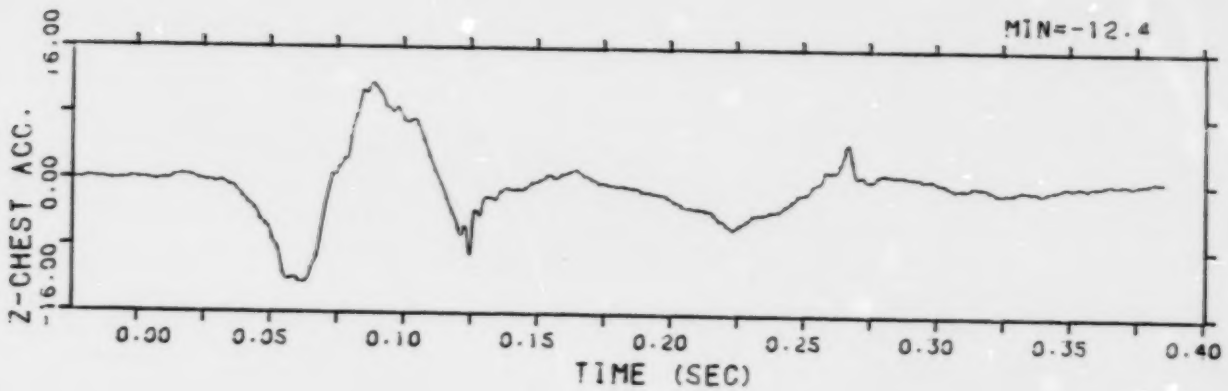

MIN=-13.7
FIL WEB ACC HI-G
16.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.40
TIME (SEC)

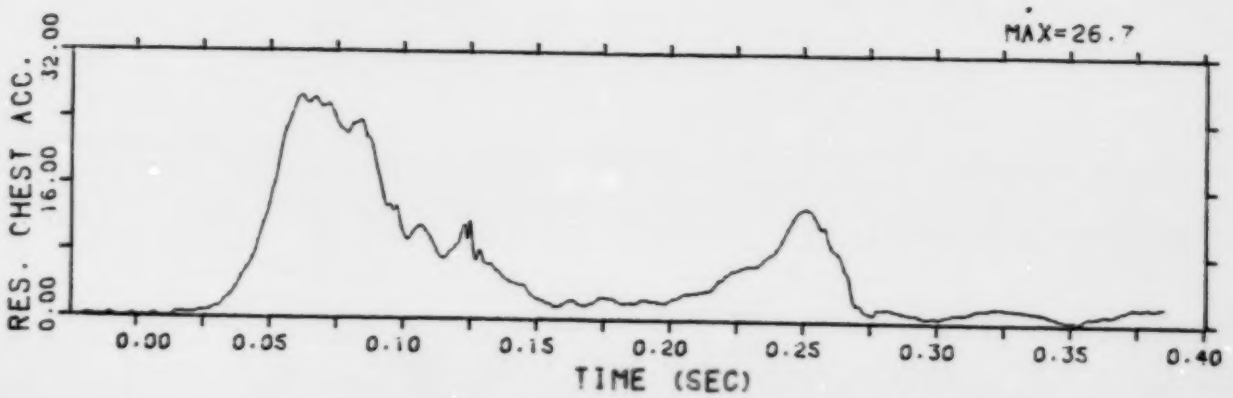

MIN=-11.3
FIL HRD ACC LO-G
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-11.9
FIL HRD ACC HI-G
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-25.7
X-CHEST ACC.
14.00
-6.00
-26.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-6.8
Y-CHEST ACC.
8.00
0.00
-8.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-12.4
Z-CHEST ACC.
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=26.7
RES. CHEST ACC.
32.00
16.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

DK:DFS480.DAT

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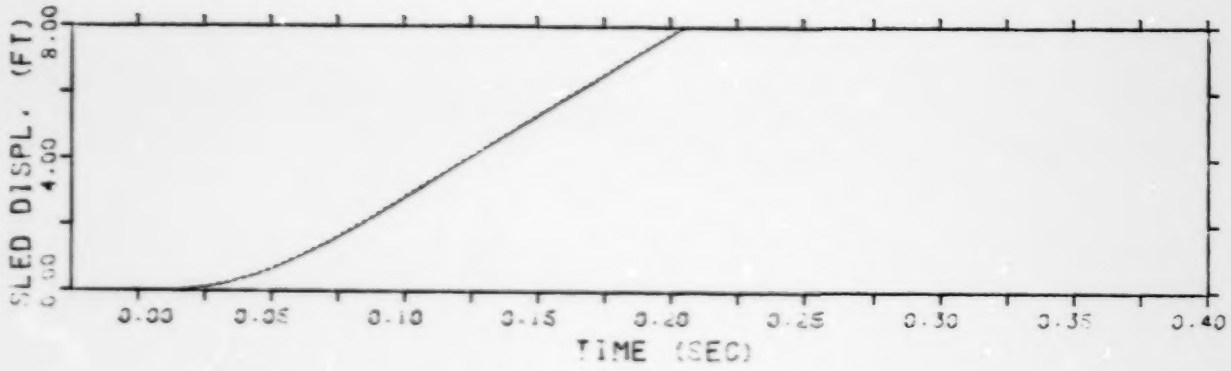
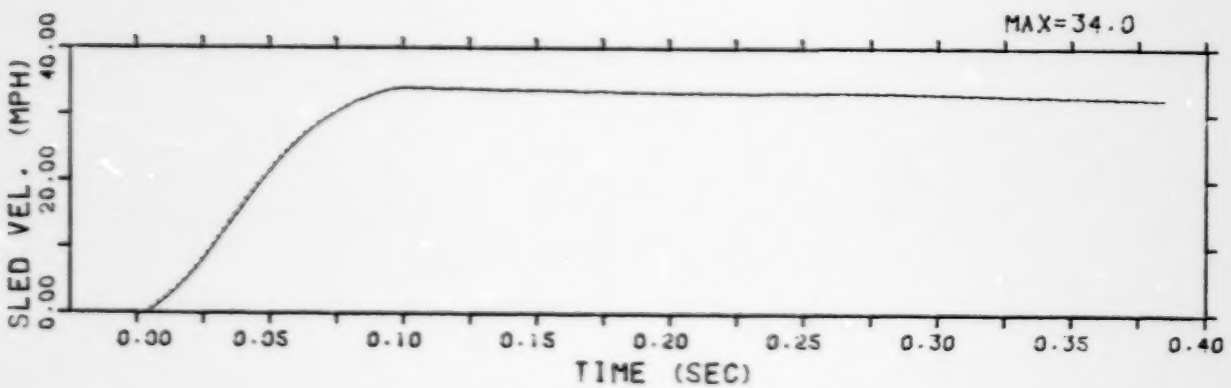
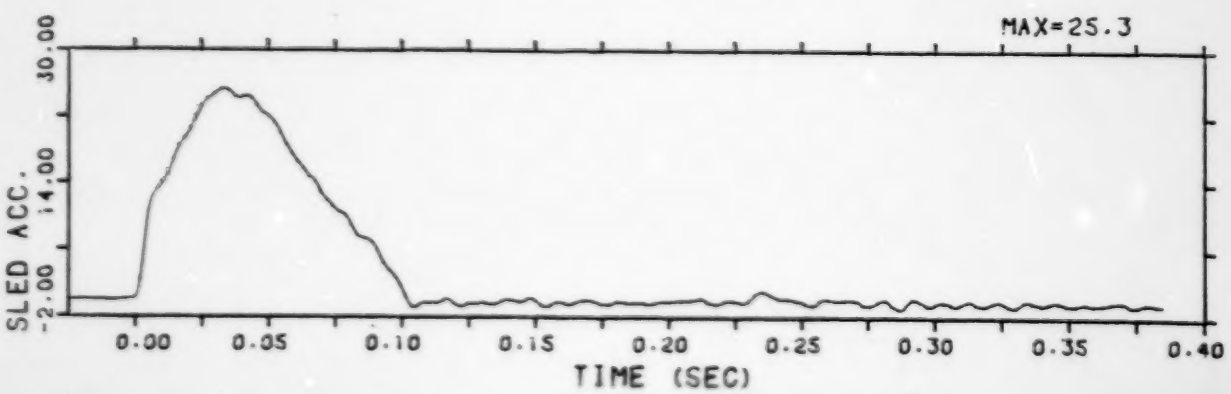
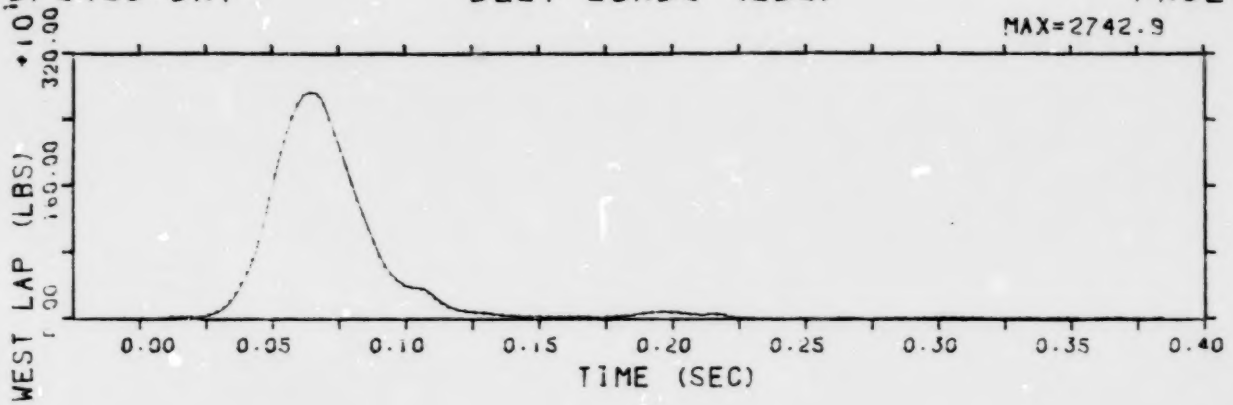
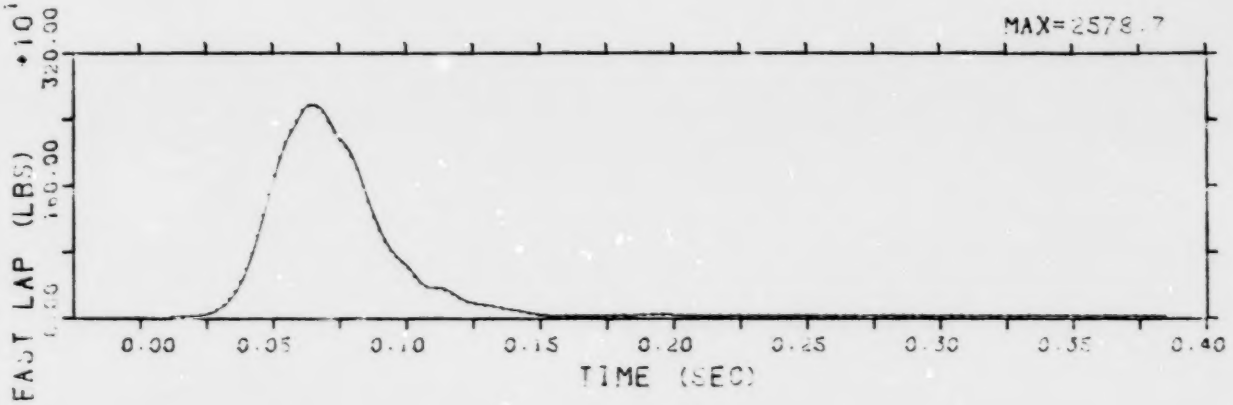
15:34:55

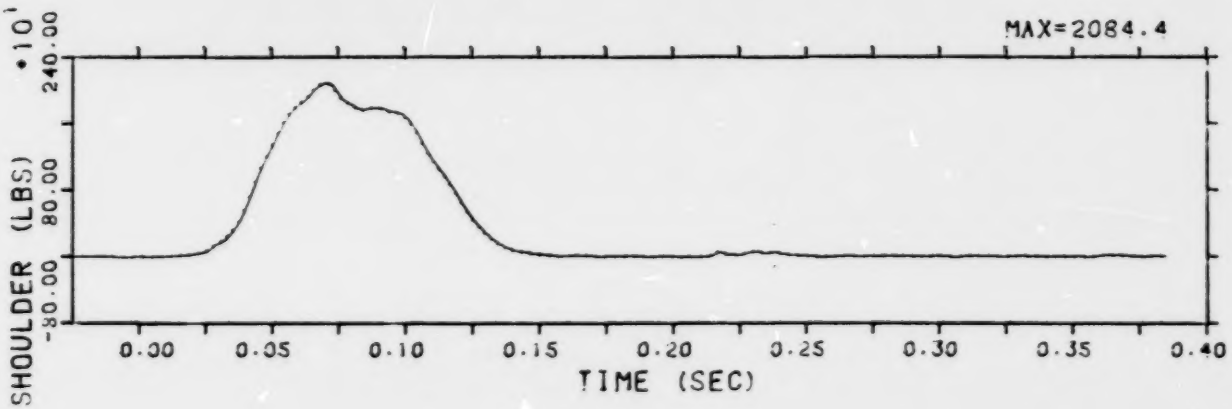


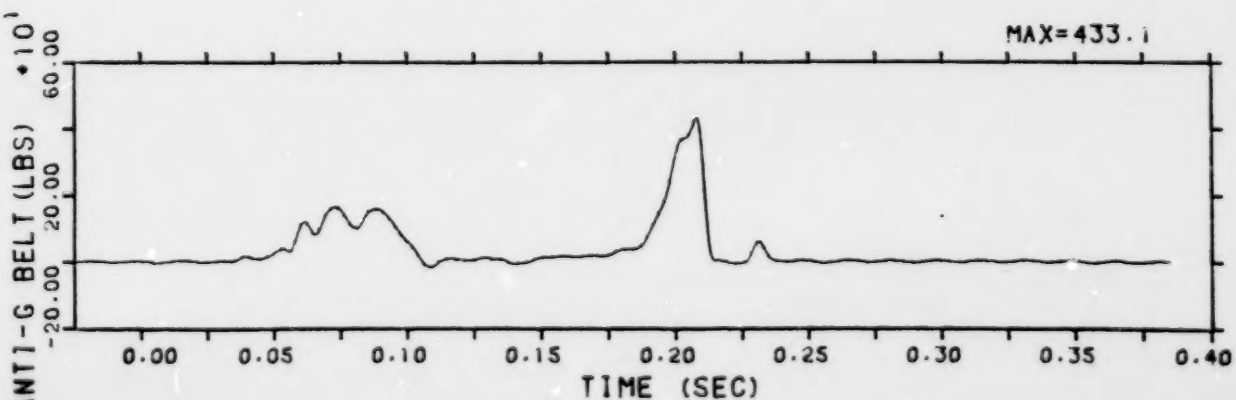


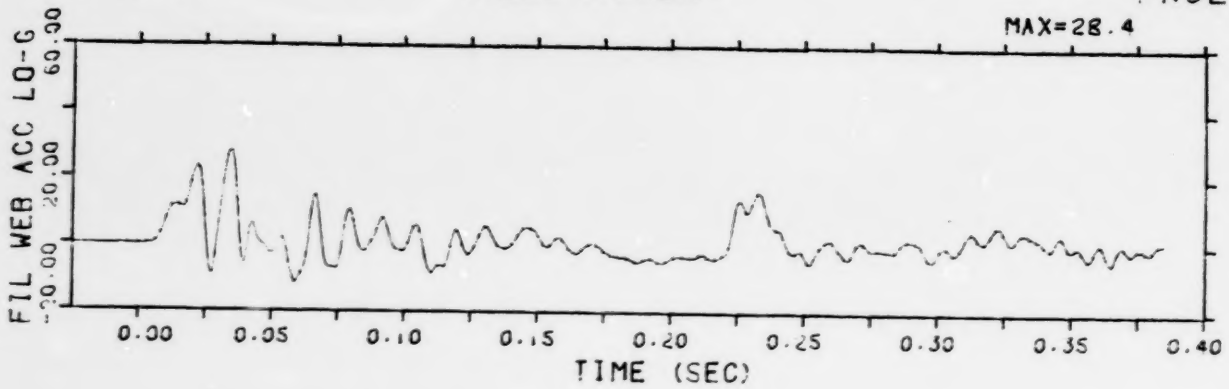


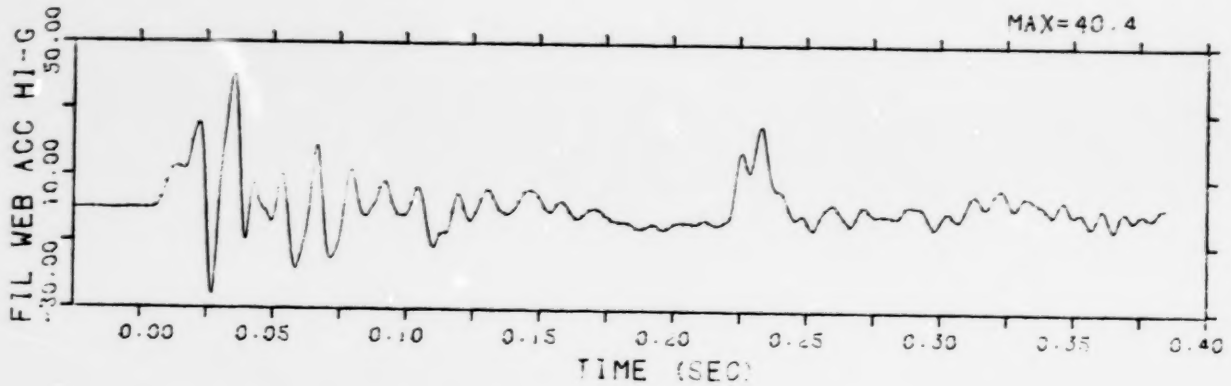

MAX=2742.9
•10¹
320.00
160.00
WEST LAP (LBS)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

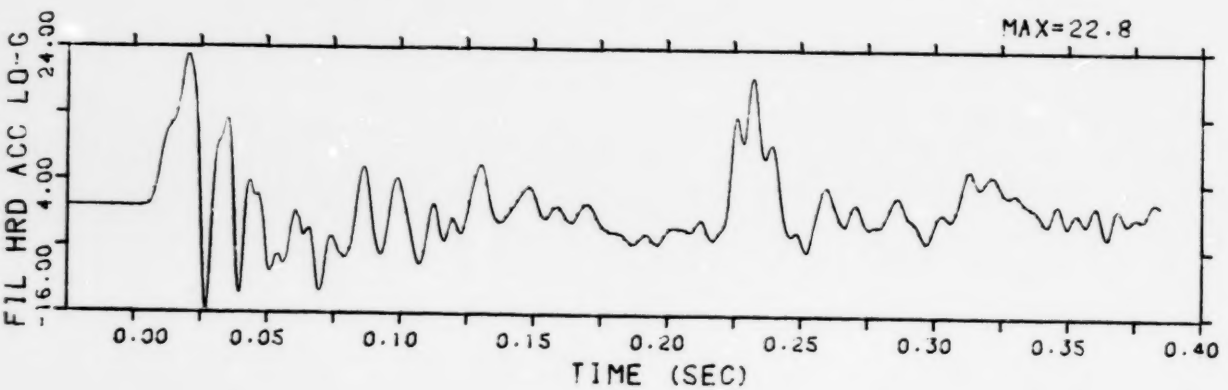

MAX=2578.7
•10¹
320.00
160.00
FAST LAP (LBS)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

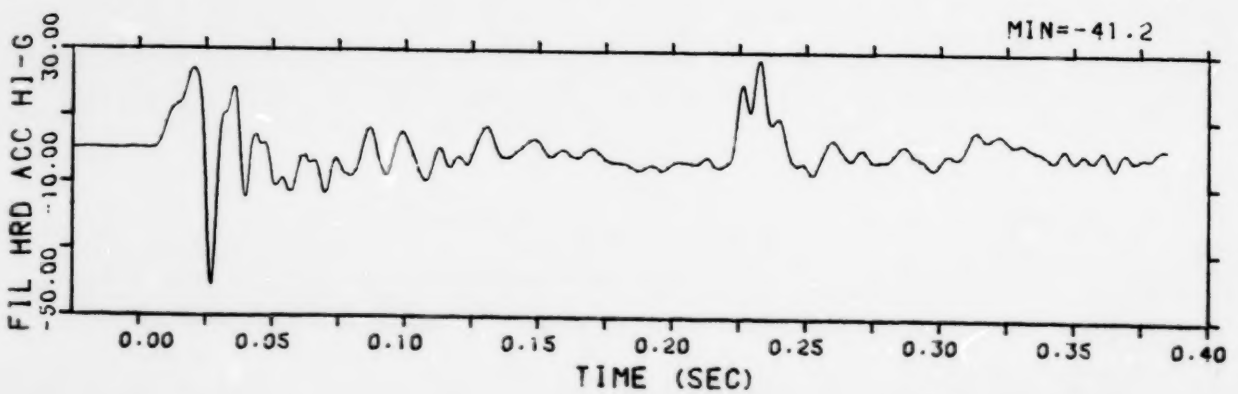

MAX=2084.4
•10¹
240.00
80.00
-80.00
SHOULDER (LBS)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

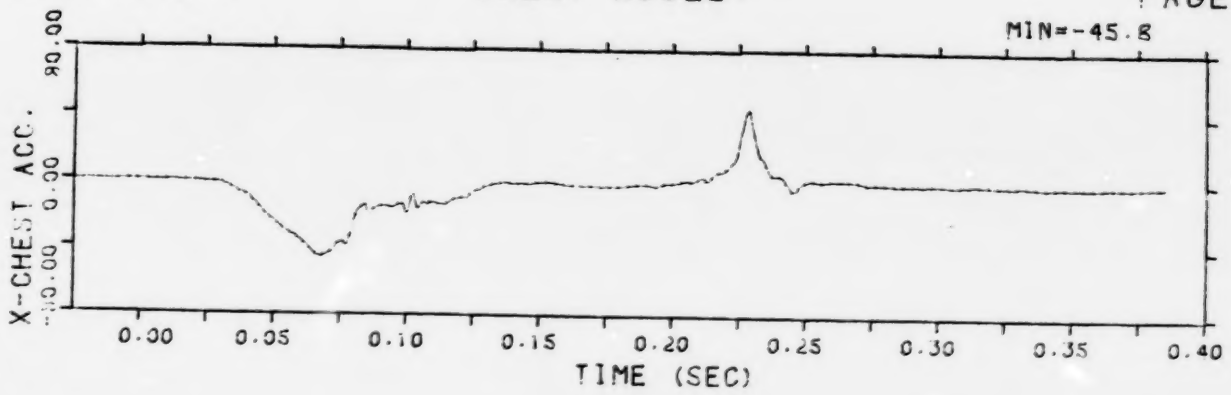

MAX=433.1
•10¹
60.00
20.00
-20.00
ANTI-G BELT (LBS)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

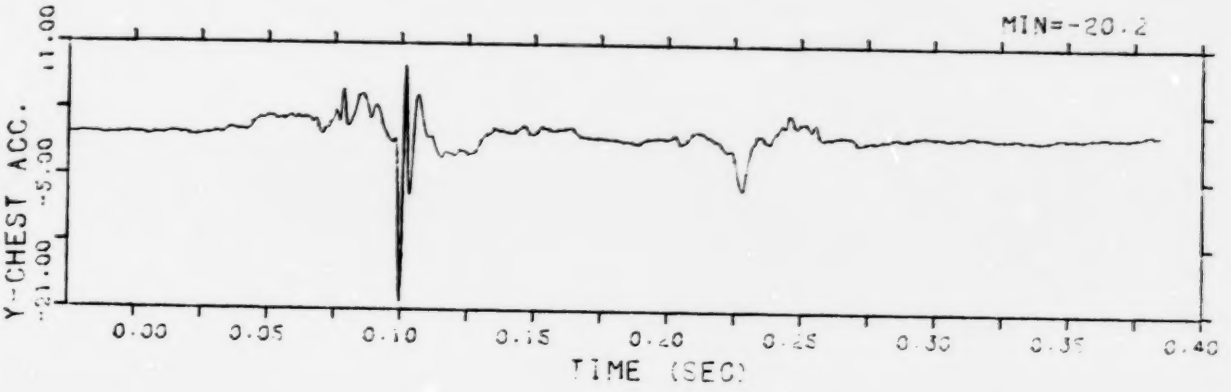

MAX=28.4
FIL WEB ACC LO-G
60.00
20.00
-20.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

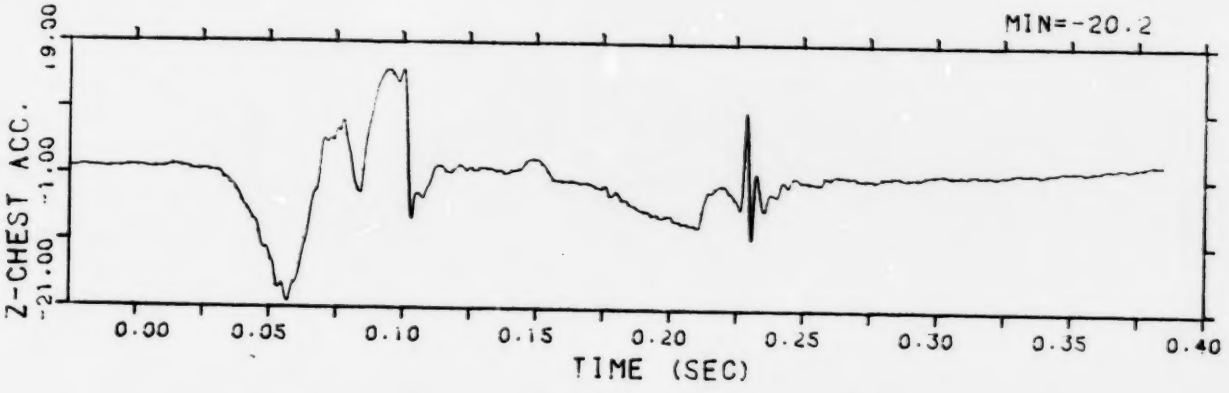

MAX=40.4
FIL WEB ACC HI-G
50.00
10.00
-30.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

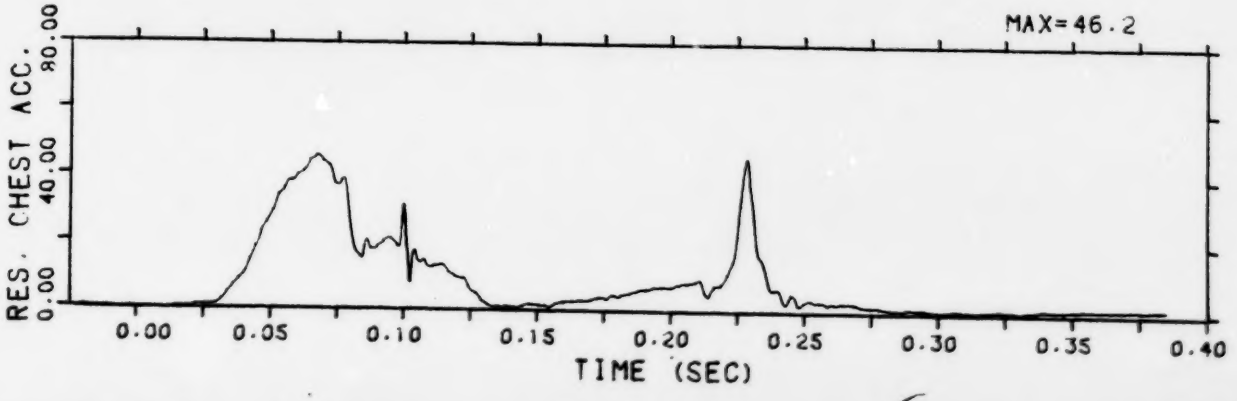

MAX=22.8
FIL HRD ACC LO-G
24.00
4.00
-16.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)


MIN=-41.2
FIL HRD ACC HI-G
30.00
-10.00
-50.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)


MIN=-45.8
X-CHEST ACC.
80.00
0.00
-80.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-20.2
Y-CHEST ACC.
11.00
-5.00
-21.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-20.2
Z-CHEST ACC.
19.00
-1.00
-21.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=46.2
RES. CHEST ACC.
80.00
40.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

DCIEM IMPACT STUDIES FACILITY

DK:DFS481.DAT

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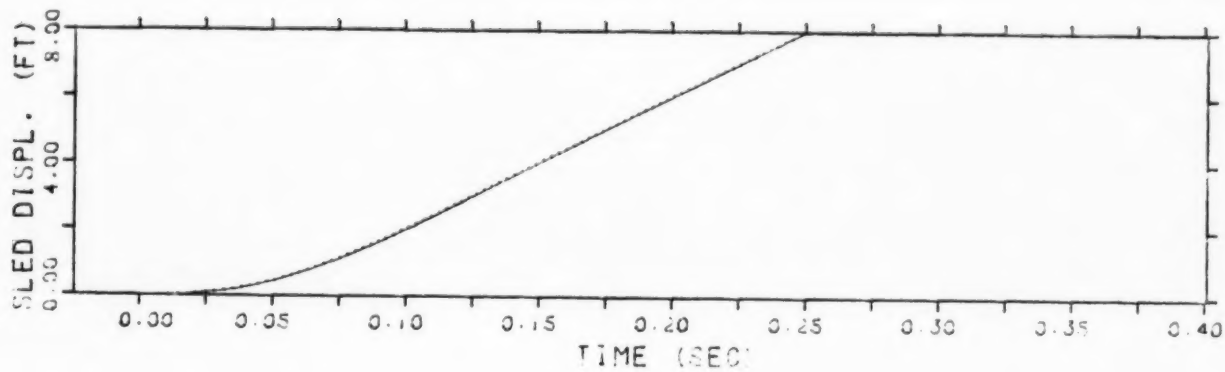
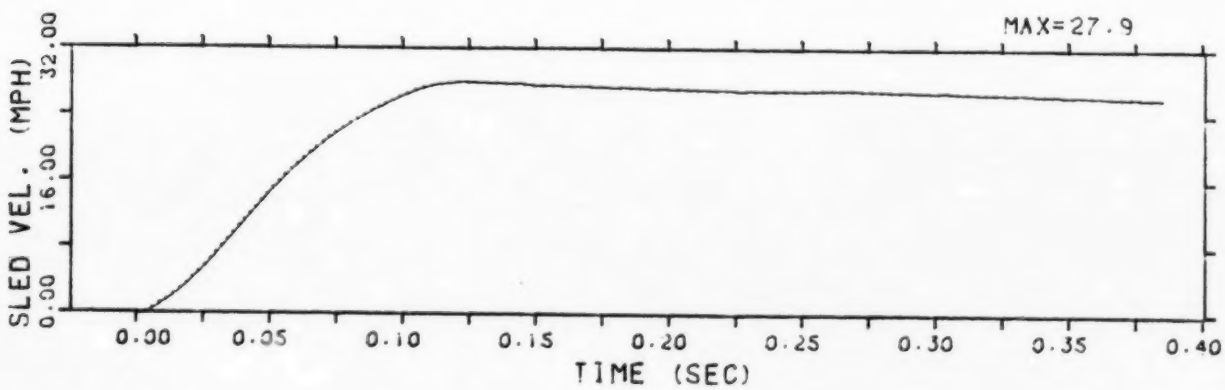
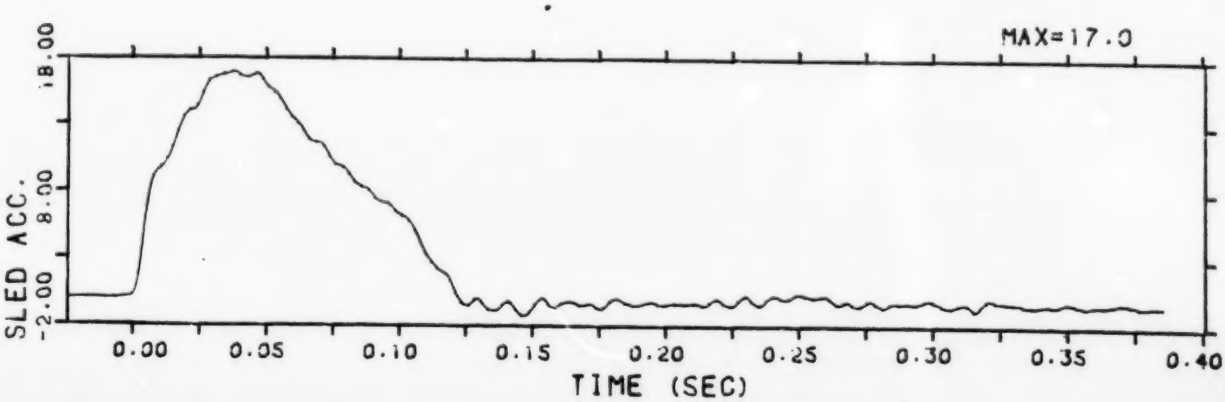
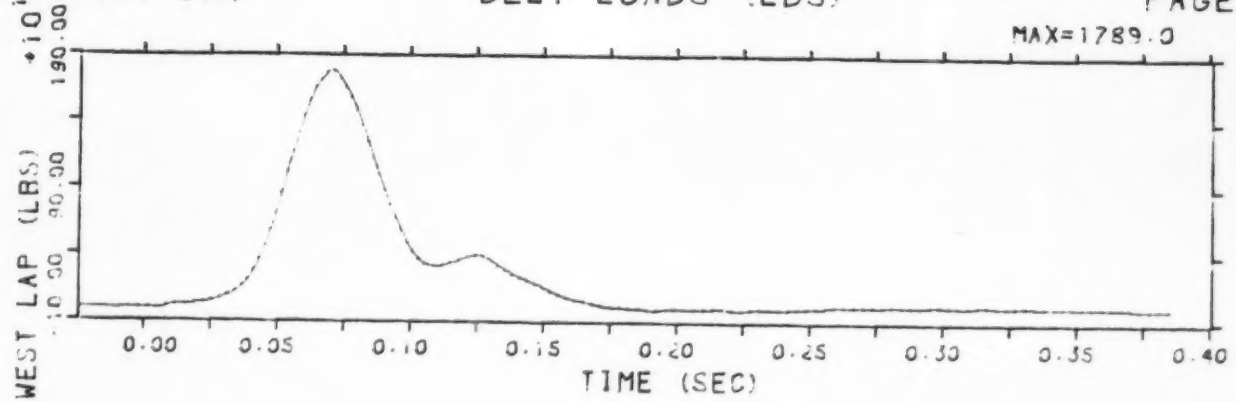
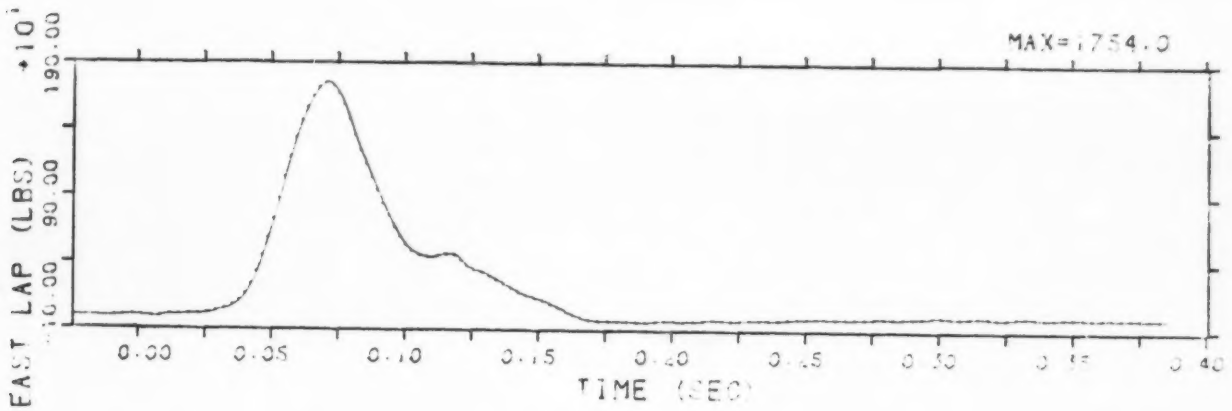
13:33:31

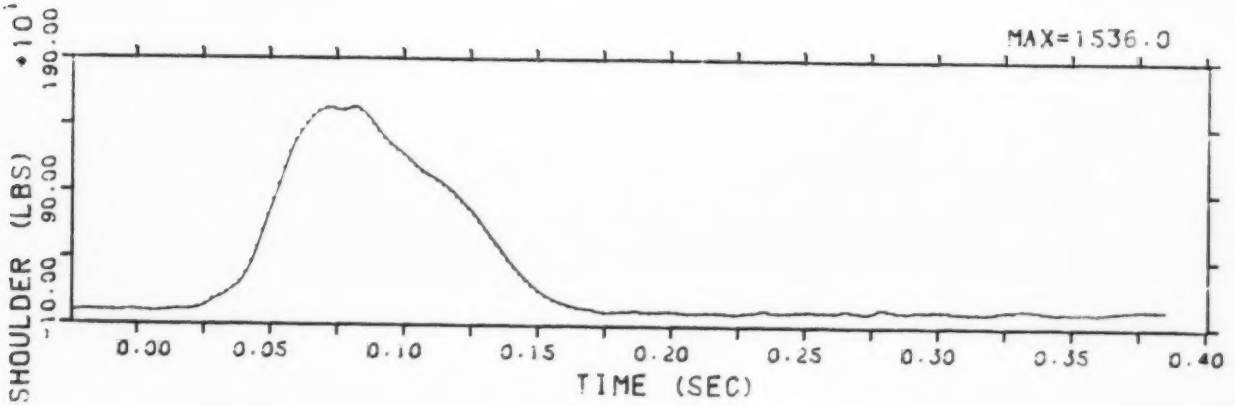


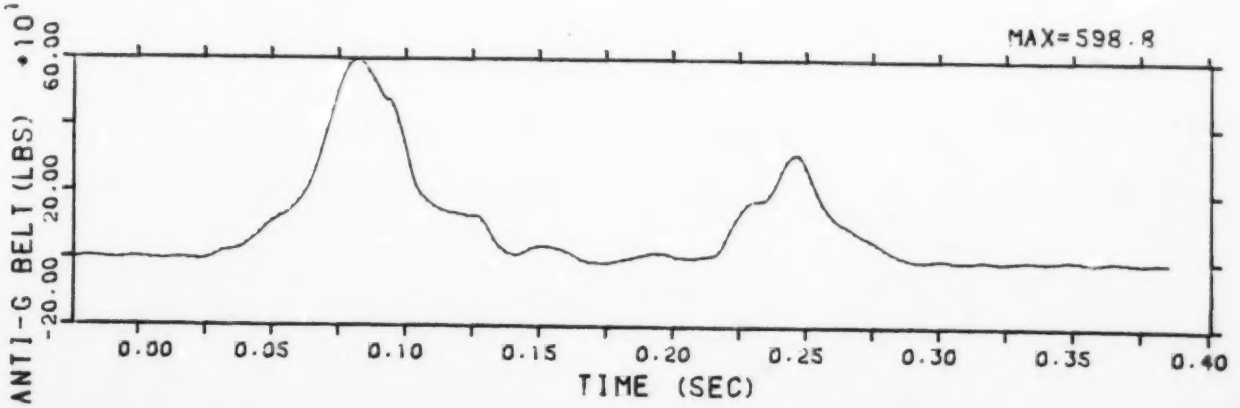


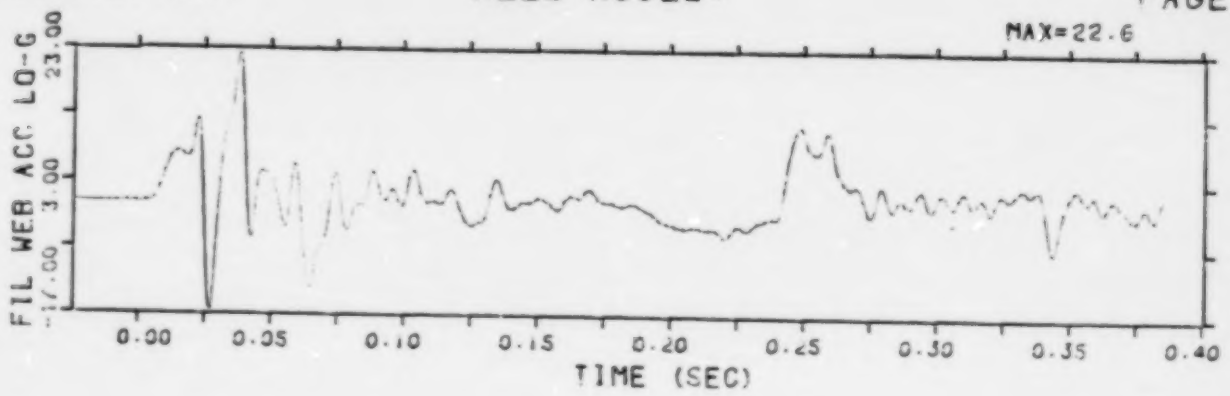


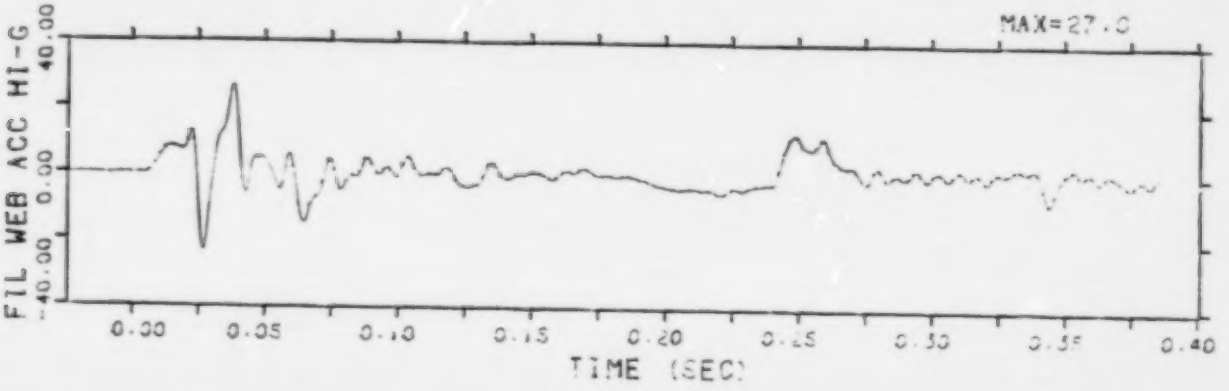

MAX=1789.0
•10³
190.00
90.00
-10.00
WEST LAP (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

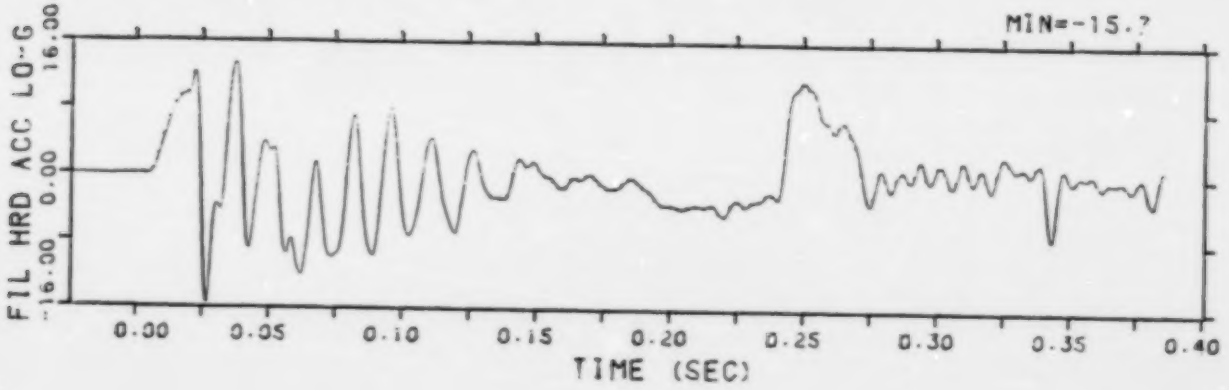

MAX=1754.0
•10³
190.00
90.00
-10.00
FAST LAP (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

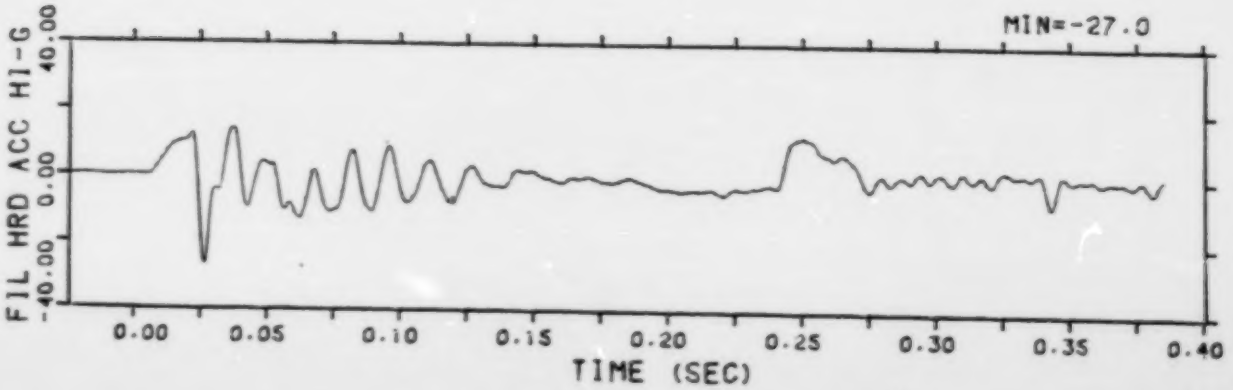

MAX=1536.0
•10³
190.00
90.00
-10.00
SHOULDER (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

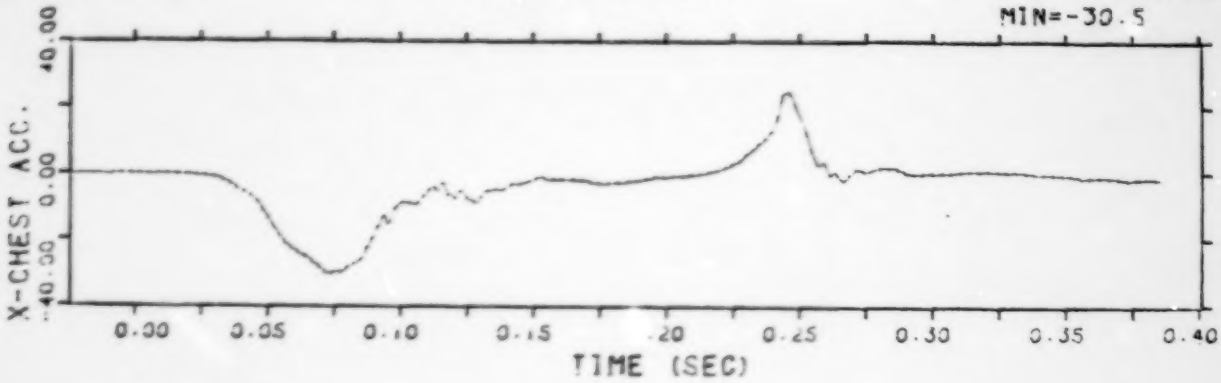

MAX=598.8
•10³
60.00
20.00
-20.00
ANTI-G BELT (LBS)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
TIME (SEC)

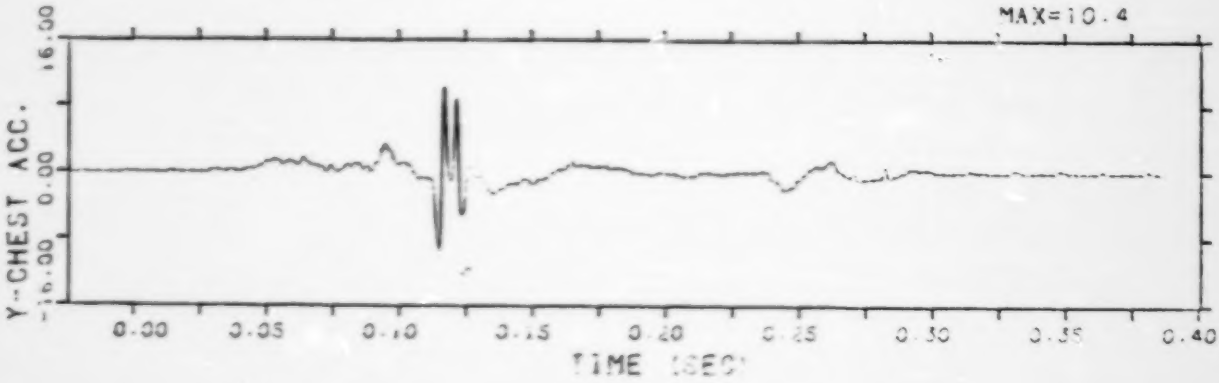

MAX=22.6
FIL WEB ACC LO-G
23.00
3.00
-17.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

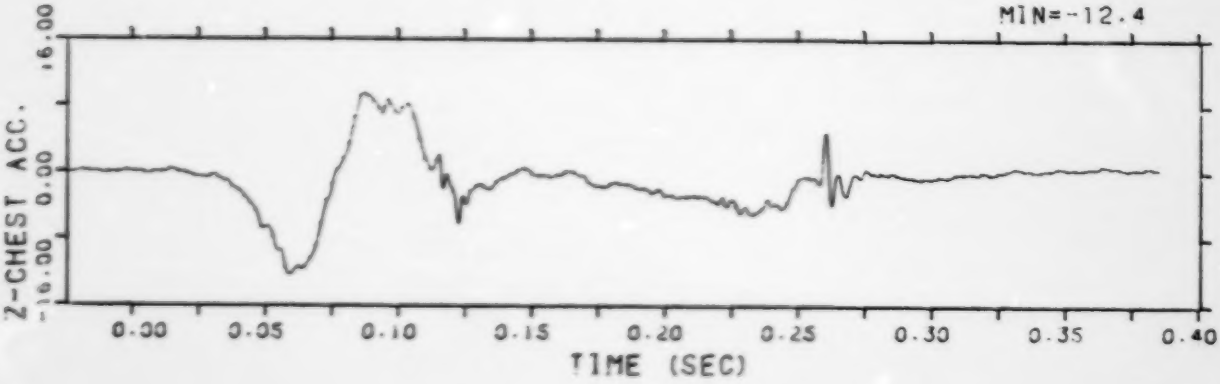

MAX=27.0
FIL WEB ACC HI-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

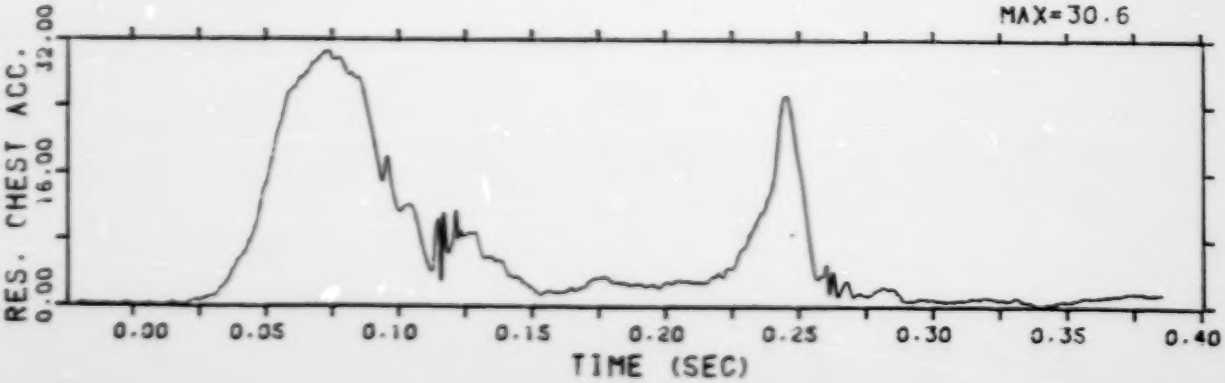

MIN=-15.?
FIL HRD ACC LO-G
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

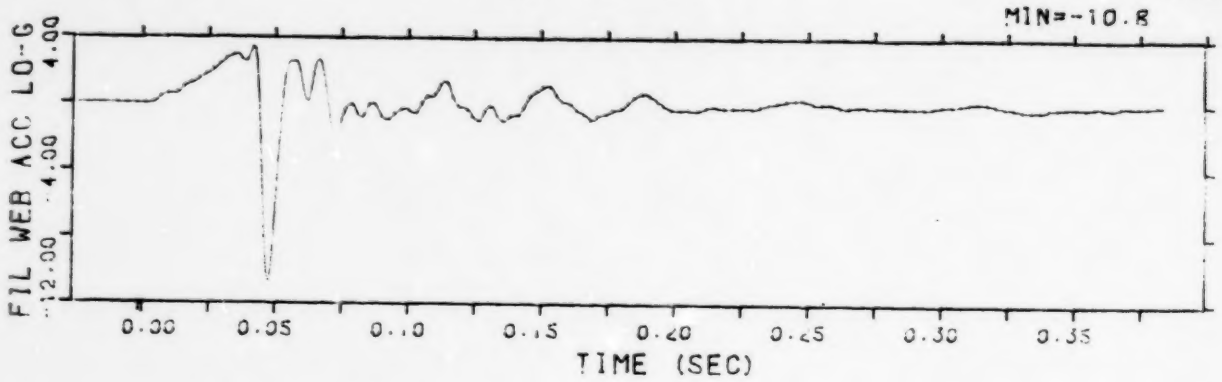

MIN=-27.0
FIL HRD ACC HI-G
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

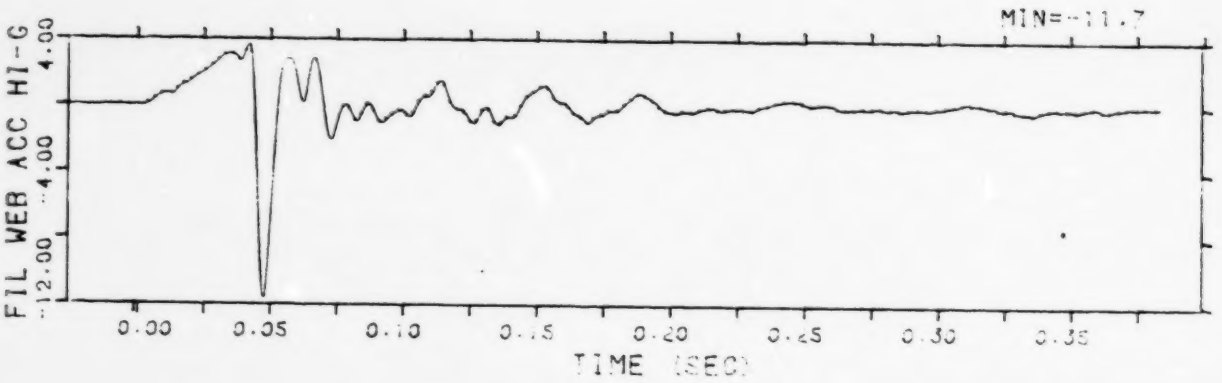

MIN=-30.5
X-CHEST ACC.
40.00
0.00
-40.00
0.00
0.05
0.10
0.15
.20
0.25
0.30
0.35
0.40
TIME (SEC)

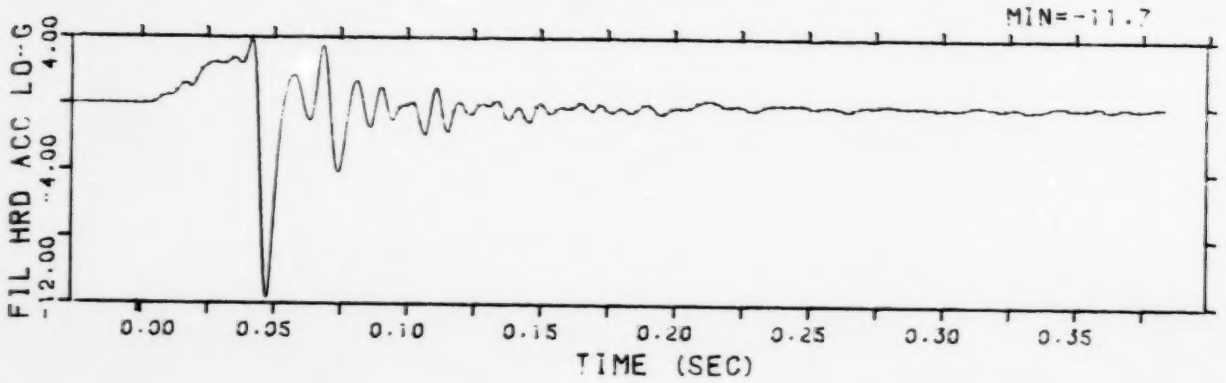

MAX=10.4
Y-CHEST ACC.
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)

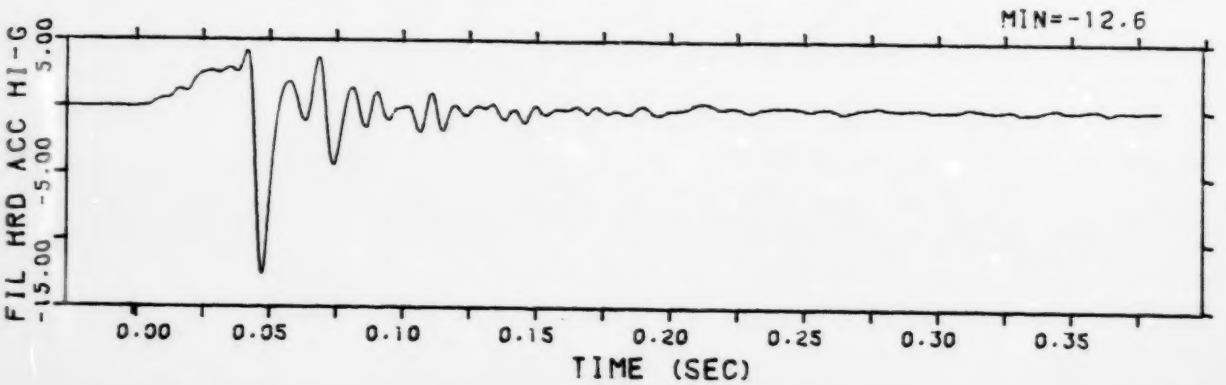

MIN=-12.4
Z-CHEST ACC.
16.00
0.00
-16.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MAX=30.6
RES. CHEST ACC.
32.00
16.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
TIME (SEC)


MIN=-10.8
FIL WEB ACC LO-G
4.00
-4.00
-12.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-11.7
FIL WEB ACC HI-G
4.00
-4.00
-12.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-11.7
FIL HRD ACC LO-G
4.00
-4.00
-12.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)


MIN=-12.6
FIL HRD ACC HI-G
5.00
-5.00
-15.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
TIME (SEC)

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QUALITY

ORIGINAL